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A PHYSICIST is required by The Radiochemical Centre for the Isotope Production Unit at A.E.R.E., Harwell, to supervise all aspects of the production of Cobalt-60, ranging from small high activity sources for therapy and radiographic applications, to large scale production of low specific activity cobalt for industrial gamma ray sources. Applicants should have an honours degree in physics or equivalent qualification and some experience of technical management. Salary £1,370–£1,825 p.a. Housing and superannuation schemes. Apply to the Personnel Officer, U.K.A.E.A., The Radiochemical Centre, Amersham, Bucks., quoting No. 2/1960/110.

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THE INSTITUTE OF PHYSICS

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Scientific Research with Rockets and Satellites

Professor Sir HARRIE MASSEY
D.Sc., F.R.S.
University College, London

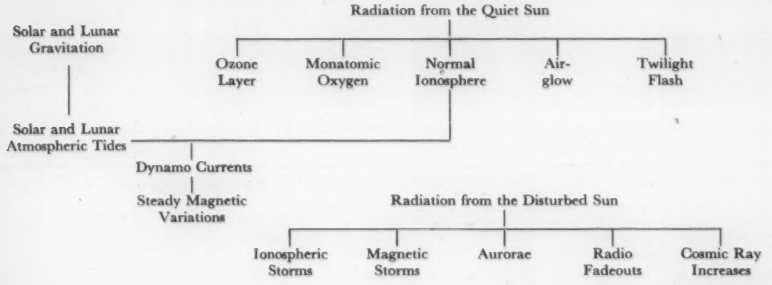
[A lecture given to the North-Eastern Branch of the Institute in Newcastle-upon-Tyne on November 6, 1959]

The great progress which has been made in the development of rocket motors of very high power and of methods of automatic guidance and control of rocket-propelled vehicles has been amply demonstrated by the launching, first of artificial satellites and then of deep space probes, capable of hitting the moon or passing beyond it to become artificial planets. The glare of publicity, however, does not fall to anything like the same extent on the scientific research which may be, and is being, carried out with the use of space vehicles.

We begin by considering some of the branches of physical science which can benefit greatly from the availability of facilities for carrying out observations in space. The term, space research, by the way, is applied to all those studies which are carried out by instruments which must be conveyed to the point of observation through rocket propulsion. In this sense space research is a unity of technique not of scientific discipline and we shall find that a very wide range of scientific study is affected, including the physics of the solid earth and of the earth's atmosphere, solar-terrestrial relations, solar physics, astrophysics and the study of the nature of gravitation.

THE EARTH'S UPPER ATMOSPHERE

The subject which has benefited most, up to the present, by the application of space research methods is the study of the earth's upper atmosphere. This we take to be that part of the atmosphere above 15 miles altitude, that is to say above the region which is responsible for weather. It is true that much was already known about the atmosphere at great heights long before the first measurements were made *in situ* by rocket-borne instruments, but there are many important aspects which cannot be studied from the ground. Perhaps the simplest way to consider the properties of the upper atmosphere is in terms of a genealogical chart showing the relation of the atmospheric effects to their solar and lunar sources.



The sun is a variable star, the degree of disturbance being indicated by the sunspot number. This goes through an eleven-year cycle, the most recent maximum being about the time of the International Geophysical Year. The radiation from the quiet sun which is present as a main background at all times includes ultraviolet and X-rays which produce the characteristic atmospheric phenomena indicated in the chart.

The ultraviolet radiation dissociates diatomic oxygen with the result that a layer relatively rich in ozone (about 1 in 10^7 of normal O_2) is produced mainly between altitudes of 15-30 kms., and at altitudes above 100 kms. oxygen is mainly in the atomic form.

Photoionization, as distinct from photodissociation, is produced by solar radiation in the far ultraviolet and X-ray regions of wavelength. This leads to the formation of the ionosphere in which there is a substantial concentration of free electrons. During the daytime the ionosphere extends upwards from an altitude of 80 kms. or so. The electron concentration is at a maximum at three heights, near 100 kms. (the E region), 180 kms. (the F_1 region) and 300 kms. (the F_2 region), the respective maxima being of order 10^5, 5×10^5 and 10^6 electrons/cc. Above 300 kms. the concentration falls off very gradually and is still above 10^5/cc. at 500 kms. At night the lower edge of the ionosphere tends to disappear due to recombination but the electron concentration remains high above 250 kms. The influence of the ionosphere on the propagation of radio waves in the broadcasting band is profound and it is of great commercial as well as scientific importance to determine and to understand the origin of the ionosphere and the nature of the variations which occur in it.

Photochemical processes initiated by sunlight also lead to the emission of a weak glow from the sky at night which, when studied spectroscopically, is found to arise mainly from the green and red forbidden lines of atomic oxygen, certain bands of molecular oxygen and nigrogen involving low excitation, and the yellow lines of sodium, the last being somewhat of a surprise. In addition to these radiations in the visible, certain infra red bands of the hydroxyl molecule are observed which are in fact the strongest features of the whole air glow spectrum.

At twilight, certain of the airglow lines, notably the oxygen red and sodium yellow lines, are strongly enhanced while one or two others, not normally present in the airglow, become quite intense. These include certain bands of N_2^+ and a forbidden line of atomic nitrogen. Here again, sunlight is responsible for producing fluorescent excitation which is observable under twilight conditions.

Solar and lunar gravity produce tides in the atmosphere as well as in the oceans but there is a curious reversal of strength between them. Whereas the lunar ocean tides are stronger than the solar, the opposite is true for the atmospheric tides. This seems to be due to a close resonance between a natural period of oscillation of the atmosphere and the solar semi-diurnal period of 12 hours. The atmospheric mode concerned is in fact one which is largely concentrated in the upper atmosphere where the tidal speeds are high, being of order 150 kms./hour at an altitude of 100 kms. These tides move conducting ionospheric regions across the lines of force of the earth's magnetic field, generating electric currents which fluctuate with solar and lunar periods. The magnetic fields of these currents at ground are responsible for the quiet magnetic variations which were known for some time to include a solar and a weaker lunar component.

The earth's magnetic field is also of primary importance in connection with the atmospheric effects which arise from the particle radiation emitted from the disturbed sun. These solar corpuscular streams are composed of charged particles, mainly electrons and protons, moving at speeds of the order of 2,000 km./sec. Because of their charge they are strongly affected by the earth's magnetic field with the result that they enter the atmosphere in narrow belts of latitude about 5° wide, centred at about 23° distance from either geomagnetic pole. The magnificent auroral displays arise from excitation by these charged particles. It is significant in this connection that auroral spectra include lines and bands which require a much higher level of excitation than those which are prominent in the airglow. Thus, while the green and red oxygen lines are still prominent, the negative bands of nitrogen which arise from excitation of N_2^+ are also strongly present.

Occurrence of auroral displays is closely correlated with that of strong disturbances of the magnetic field at ground and of the ionosphere, often of such intensity as to be called storms. In some way or other these are also due to the solar corpuscular emission, partly in producing extra ionization over the auroral zones but partly arising also in less well understood ways.

Electromagnetic radiation from the sun may also be enhanced in certain wavelength regions when the sun is disturbed, and this seems to be responsible for radio fadeouts by producing excess ionization at levels in the atmosphere so dense that strong absorption of radio waves results and long distance transmission of radio signals becomes impossible.

In addition to the solar and lunar effects we have mentioned, it is important to remember that meteors of various sizes are also incident on the atmosphere from outside. Unless they are exceptionally large, meteors are all burnt up before penetrating to an altitude below 80 kms., but micrometeorites with diameter less than 5×10^{-4} cm. are too small to heat up to evaporating temperature and eventually settle on the surface.

Finally, we have the very important cosmic radiation existing mainly of protons with energies greater than 500 MeV together with energetic alpha particles and other nuclei, all entirely stripped of the usual atomic electrons. Most of these primary cosmic ray particles produce secondaries in the atmosphere at a level near 15 kms., but the more highly charged components interact at considerably higher altitudes.

THE USE OF ROCKETS IN VERTICAL SOUNDING

It is obvious that there is a wide field for study of the properties of the upper atmosphere and of their relation to the sun. As we have already said that much was done before rocket propulsion became available, it is important to consider why, in fact, the use of these expensive new techniques can be justified.

This may be answered immediately when we realize how important an influence is exerted by the radiations from the sun. In the course of producing upper atmospheric effects, these radiations are absorbed and never penetrate even to levels available to balloons. The only way to study them is to transport instruments up to altitudes far above those at which they are strongly absorbed. Such vital observations can only be made if rocket propulsion is used.

This possibility which is opened, of making a systematic study of the solar radiation before it is affected by the atmosphere, would alone be sufficient justification for the use of rockets, but it is by no means the only example of an important measurement which cannot otherwise be carried out. Thus it is not possible to determine the ionic constitution of the ionosphere at different heights nor to study the variation of electron concentration at altitudes above a layer maximum until it reaches a value greater than at that maximum. Determination of the height distribution of the ionospheric currents is another important task which can only be attempted by making magnetic field measurements through the regions in which the currents circulate, and so on. Even those properties which can be studied to some extent from the ground are capable of much more detailed and precise study once direct measurement is possible. An outstanding example of this is the determination of the height of the regions from which the different air glow lines and bands are emitted. It applies also in full force to the study of atmospheric structure—pressure, density, temperature, composition and wind distribution.

ATMOSPHERIC EXPERIMENTS

There is a further important direction of research which may be pursued once the upper atmosphere is accessible to instruments. Atmospheric experiments, as distinct from observations, become possible. The distinction is important. When making observations the aim is to measure some property of the atmosphere which is affected as little as possible by the means adopted to make the measurement. In an experiment, however, conditions are changed deliberately in some controllable way and the results of the change observed. There is no need to stress the great importance of experiment in all science. The first example of an upper atmospheric experiment was one carried out in 1955 in the United States in which 2 lbs. of sodium vapour was ejected into the atmosphere at twilight from a rocket at an altitude of 80 kms. This fluoresced strongly in the sunlight and the yellow glow could be observed for several hundred miles for as long as 20 minutes. Information about wind distribution at the height of the glow can be derived from observations of its motion, while the temperature at the same height can be obtained from measurement of the width of the sodium lines emitted. Many other possibilities arise and it is by no means fantastic to regard the upper atmosphere as an ideal laboratory for photochemical experiments, free from all surface effects. We shall have occasion towards the end of this article to say something about the largest scale experiments ever performed, which operated essentially on the same principles.

ARTIFICIAL SATELLITES AND DEEP SPACE PROBES

Before going on to discuss other applications, it is important to distinguish the role of vertical sounding rockets, artificial earth satellites and deep space probes. If fired vertically, a rocket makes an ascent to an altitude of a few hundred kms. and returns to earth in a matter of a few minutes only. This is a great disadvantage for studying atmospheric properties which vary with position over the earth as well as with time of day, season and epoch in the sunspot cycle. It is in this connection that one thinks of artificial satellites capable of revolving for months or years at high altitudes. Sufficiently reliable instruments contained in such satellites would be able to make systematic observations during these long periods. For this reason, whenever practicable, it is better to work with instruments in satellites rather than in vertical sounding rockets—in one month, instruments in a satellite can take as many observations as the same instrument launched in 8,000 vertical sounding rockets. It is important, however, to note the proviso—whenever practicable!

Because of air resistance the orbit of a satellite at first becomes more and more nearly circular, while the perigee distance (closest distance to the earth) contracts gradually at first and then more rapidly until the satellite spends so much time in the dense atmosphere that it burns up. If the initial orbit has a perigee distance less than 180 kms., the lifetime of the satellite will be very short (unless the apogee—the greatest distance from the earth—is very great indeed). It follows that, for studying the many important regions of the atmosphere below 150 kms., it is still necessary to use vertical sounding rockets. Above that altitude, artificial satellites have outstanding advantages for systematic observations.

It is possible to launch satellites in highly eccentric orbits so that the apogee distance is comparable with the distance of the moon from the earth, in which case observations well out into interplanetary space may be carried out on a systematic basis. This has been accomplished, for example, in the present Russian vehicle which incidentally as a preliminary task carried out a circumnavigation and reconnaissance of the moon. An alternative possibility is to launch the vehicle at a speed greater than the escape velocity from the earth so it passes along a hyperbolic orbit to become a new minor planet. With the present range of radio communication, such launchings are very uneconomical from the point of view of acquiring scientific information about interplanetary space—everything is over in a few days.

There are the further possibilities of vehicles launched for other specific purposes such as the study of the immediate environments of the moon and the nearer planets. Ultimately it is an advantage, even in these cases, to arrange for systematic observation by launching the vehicle to become a satellite of the body under study, at least for some time. This is already being aimed at for the moon, but many more pressing problems need to be solved before one considers the problem for the planets.

APPLICATIONS OF SPACE RESEARCH IN ASTRONOMY

So far we have considered only those applications which may be made of rocket and satellite vehicles to the study of the earth's upper atmosphere and of solar-terrestrial relations. An even greater prospect is opened out for astronomy generally. Once an observing station is available outside the atmosphere the universe may be viewed in radiations of all wavelengths—we are no longer restricted to the two narrow bands in the visible and in the radio wavelength region which are able to penetrate through the atmosphere to the ground. The importance of this is clear when we note how much of value has been obtained in the few years since the war by the development of radioastronomy. A preliminary scan of the northern sky in radiations of wavelength 1,225-1,350 Å has been made by Friedman and his collaborators using electronic equipment, with angular resolution 3°, carried to 146 km. altitude in an Aerobee rocket launched on March 28, 1957. The results reveal areas of strong emission of this ultraviolet radiation which do not coincide with visible nebulosities. With equipment carried in satellites, boundless opportunity for astronomical work in this new field is offered. A start can be made with the relatively crude satellites at present available. The next step is to develop means of stabilization in space of a platform within a satellite on which instruments for astronomical observation may be mounted.

It is important to remember that a useful extension of the existing wavelength range of astronomical observation can be obtained by using balloons as instrument carriers. Such possibilities should be exploited as thoroughly as possible, restricting the use of satellites to the wide range of wavelengths which are not available to observations from balloons.

A further point to notice is that full use can be made of the astronomical possibilities, provided the satellite spends much of its time outside the main absorbing atmosphere. When this is achieved it is of no advantage to use satellites in more distant orbits—the breakthrough occurs once the satellite circulates at a distance of 200 miles or so.

OTHER SCIENTIFIC APPLICATIONS

In addition to looking outward, the instruments in a satellite may look inward to obtain a synoptic picture not only of atmospheric circulation but of the radiation from the earth. The value of such global observations for meteorology is bound to be great.

If sufficiently accurate observations are made of the position of a satellite at different times it is possible, from analysis of the variation of the orbit with time, to obtain information, not only about the air density, at the perigee, but also about the earth's gravitational field. In this way contributions may be made to the study of the figure and constitution of the solid earth as well as to geodesy.

There are further, rather more distant but nevertheless intriguing, prospects of studying the nature of gravitational forces. These forces are less well understood than any of the other three main types—the forces binding nucleons together in atomic nuclei, electromagnetic forces and the so-called weak interactions which are responsible for beta-radioactivity, meson decay, etc. The only theory which attempts to analyse the nature of gravitation in fundamental terms is the General Theory of Relativity proposed by Einstein. Although this theory has many attractive features it rests on an extremely slender observational basis. One of its predictions concerns the effect of a gravitational field on the rate of a clock. It is by no means out of the question to test this by very precise comparison of the rate of an atomic clock in a satellite with that of a similar clock on the earth's surface. Advantage may be taken of the build-up of any difference from revolution to revolution. Before any experiment of this kind could be undertaken there would need to be considerable developmental work directed towards the construction of atomic clocks of a sufficiently small size.

SOME REMARKS ON TECHNICAL REQUIREMENTS

For successful use of instruments in vertical sounding rockets it is necessary that they should be compact and sufficiently robust to withstand the effect of vibration and high acceleration. It is essential also that the path of the rocket be accurately tracked so that it is possible to associate a particular measurement with a particular location in space. Both radio and optical methods are used for this purpose and the appropriate equipment is a routine requirement at a rocket launching range. Another vital problem which must be solved is that of recovering the data gathered by the onboard instruments. For most purposes it is not necessary to do this by actual recovery of instruments or records from the rocket case after its return to earth, although this may be done if essential. Normally, arrangements are made for the observations to be transmitted to ground during the flight in the form of coded radio signals from an onboard transmitter—the technique of telemetry.

Similar techniques are required for successful use of instruments within satellites. In such cases telemetry is the only means of recovering data—physical recovery of the satellite still presents an extremely difficult problem. The problem of determining the track of a satellite with precision is also quite difficult. It is best to distinguish three steps—the initial acquisition, the steady circulation with only slowly varying parameters and the final rapid descent into the atmosphere. For the most accurate tracking during the main stage optical methods are the best even though the problems differ in some important respects from those associated with the usual problems of optical astronomy. The high speed of the satellite is one of the major new features. Optical methods are not suitable for locating a satellite initially after launching as they depend on prediction of approximate time and bearing for directing the observing equipment appropriately. It is best to include a radio beacon for acquisition as radio direction finding may then be carried out without difficulty. Although the same method may be used in the final stage of a satellite's life it may well be that the radio beacon has ceased to transmit by that time in which case radar methods may be used.

Careful attention must be paid to the need for temperature control of a satellite for the instruments, including the power supplies, will only function in an environmental temperature which falls within a quite narrow range. Control may be exercised by appropriate choice of surface coating for the satellite shell since the

temperature is determined by an equilibrium between radiation received from the sun and earth and that radiated by the shell. Automatic control may also be achieved by use of a shutter system.

Apart from the need to employ instruments which will function successfully without maintenance for periods of several months, there is the important question of power supply. This has been largely solved by the development of solar batteries although, even here, the fact that provision must be made for storage in order to operate the equipment when the satellite is in darkness, leads to difficulty.

With deep space probes the main problems are those of guidance and control to achieve the desired trajectory, of accurate tracking and of data recovery over great distances. There is, of course, the primary requirement of adequate thrust to gain the necessary speeds but this can be regarded as solved in practice for instrument payloads of a hundred pounds or more. Once the thrust is great enough to launch a satellite requiring a launching speed of 18,000 miles per hour it is only necessary to increase this speed $\sqrt{2}$ times to project the body into a hyperbolic orbit, leaving the confines of the earth to become a satellite of the sun. The degree of guidance and control which can be achieved to-day is demonstrated by the launching of the third Russian lunar probe. This remarkable operation also showed what may be done by storing data within the vehicle until transmission is commanded by a signal from the ground. In some of the earlier lunar probes, including the first American artificial planet, data was transmitted back successfully from a distance of over 400,000 miles.

Probing in the neighbourhood of the nearer planets is immensely more difficult than near the moon. Not only are the tolerances on guidance and control so much tighter but there is the basic difficulty that the distance of the planet at any time is not known to within 10,000 miles—a small percentage error but a serious one for close probing.

SOME SCIENTIFIC RESULTS ALREADY OBTAINED

Studies of solar radiation carried out with spectrographs, photoelectric detectors and photon counters, have shown that, beyond the short wavelength ground cut-off at 2,900 Å, the intensity at first falls below that which would be expected of a black body at 6,000°K. This trend begins to reverse below about 1,500 Å and in the soft X-ray region from 1-50 Å the intensity greatly exceeds the black body value. No surprise need be caused by this because it must be remembered that the sun is surrounded by an extensive corona in which the matter is at a kinetic temperature of 10^{6}°K—the X-rays undoubtedly are emitted from this region. It seems likely that the ionization in the E region of the ionosphere is due mainly to the solar X-rays, a result suspected several years ago but incapable of proof until these measurements were made from vertical sounding rockets. Although this represents a good start an immense amount of systematic observation is necessary. Special attention must also be paid to the practically difficult wavelength range just below 900 Å as it seems likely that these radiations are responsible for the production of the F region of the ionosphere.

As mentioned on p. 34 the atmospheric oxygen above 100 km. altitude is nearly in atomic form. It is not possible, from theoretical considerations based on the photochemical equilibrium, to determine the proportional concentration of the oxygen which remains in the atomic form at any particular altitude above 100 kms. because this depends on the degree of mixing due to atmospheric motions. By measuring the variation of the intensity, with height above 100 kms., of radiation of wavelength 1,445–1,500 Å which is selectively absorbed by O_2, it is possible to deduce the O_2 concentration at each height. In this way it has been found that, even at as high an altitude as 180 kms., this concentration is as much as one-tenth of that of atomic oxygen. This shows the great importance of mixing, for the O_2 would be in quite negligible concentration if photochemical equilibrium prevailed.

The study of the nature and relative concentrations of the ionic species in the ionosphere, by flying mass spectrographs in rockets, proved more difficult than anticipated, partly because of complications due to charging-up of the rocket case and to contamination by rocket gases. It seems fairly well established now, however, that up to altitudes of about 180 kms. the main positive ions are of nitric oxide (NO^+). This does not mean that neutral nitric oxide is an important atmospheric constituent. It is only necessary for a small amount to be present in order that the exothermic reactions

$$O^+ + N_2 \rightarrow NO^+ + N,$$
$$O_2 + N_2 \rightarrow NO^+ + NO,$$

should build up the NO^+ concentration to the observed levels. There is no evidence of the presence in appreciable concentration of any negative ions though the ubiquitous ion NO_2^- is found to be present to a small extent.

The existence of dynamo current systems at equatorial latitudes has been confirmed by observations of the variation of the earth's magnetic field with height, the rate of change exhibiting a sharp discontinuity on passing through a current layer.

These are only a few of the important results obtained with the use of vertical sounding rockets. The observations of the ultraviolet radiation emitted from the northern sky, the first contribution to ultraviolet galactic astronomy, has already been referred to, as well as the first atmospheric experiment with ejected sodium vapour. There are many observations of atmospheric pressure, density, temperature, wind distribution, ozone concentration, height of emission of the green oxygen line and of the sodium line in the night air glow, electron concentration in the ionosphere, etc., which cannot be dealt with in the present article but are nevertheless of great value for upper atmosphere physics.

We shall say nothing more about the extensive results obtained with use of vertical sounding rockets except those concerned with the observation of particle radiations, as they are a prelude to the most important observations so far made from satellites and space probes.

THE RADIATION BELTS AROUND THE EARTH

Some years ago van Allen and his collaborators carried out observations of the intensity of particle radia-

tion at altitudes of 100 kms. or so, using unshielded geiger counters flown in rockoons (these are rockets launched at a considerable altitude from balloons, thereby avoiding the air drag from the dense lower atmosphere). They found that the counting rate shows a strong maximum over the auroral zone. This was almost certainly due to the presence in this zone of X-rays with quantum energy between 10^4 and 10^5 ev. as was confirmed with further observations using pulse height discrimination. The X-rays presumably arose from impact of incoming electrons of comparable energy, with atmospheric atoms. These electrons are likely to be among the agents responsible for auroral excitation.

In 1957 van Allen took the opportunity of including similar unshielded counters in the first Explorer satellite launched from the U.S.A. The results obtained were very surprising. When the satellite was within a few hundred miles of the earth the counting rate was as expected for cosmic rays but, at altitudes of 1,000 miles or more, no counts were recorded. This behaviour occurred regularly, indicating that it was not due to instrumental failure. Similar equipment in Explorer III, launched in 1958, which used data storage and transmission on command, gave the same results. van Allen considered that the effect must arise from a great increase in the radiation intensity above altitudes of 1,000 miles. If sufficiently great this would choke the counters, due to the finite dead time after each count. This was confirmed by laboratory experiments which showed that choking would indeed occur if the radiation intensity reached a level 10^4 times that of the cosmic radiation. Accordingly, van Allen introduced in Explorer IV, launched on March 26, 1958, counters capable of recording these high intensities. The results obtained confirmed his interpretation of the early records and established the existence of a region of high intensity of particle radiation. Although the equipment was not elaborate enough to provide detailed information on the nature and energy distribution of the particles it seemed clear that they were much less energetic than the cosmic rays.

About this time Sputnik III was launched from the Soviet Union. It included apparatus for the observation of charged particles which was capable of greater energy discrimination than van Allen's apparatus in Explorer IV. Also the orbit was of greater inclination (65°) than that of the American satellites (33°), so the radiation intensity could be explored at higher latitudes, including the auroral zones. A marked increase in radiation intensity at altitudes above 200 kms. was found at these latitudes the mean energy of the particles concerned being of the order of a few 10^4 ev. Some evidence was obtained which suggested that this zone of intense radiation was distinct from that observed by van Allen at equatorial latitudes in that it occurs at lower altitudes and does not include any appreciable proportion of particles with energies as high as a few MeV.

The existence of two separate zones of high intensity of particle radiation was established beyond doubt from observations made using counters included by van Allen in Pioneer I, the American deep space probe launched on October 11, 1958, which attained an apogee distance of 71,300 miles. The inner zone is most intense at a distance of between 1,000 and 2,000 kms. but the second is most concentrated at 15,000 kms. distance. Although the data obtained on this flight referred to points on a single trajectory, taken together with the data from the Explorers and from Sputnik III it pointed strongly to a close association between the radiation belts and the earth's magnetic field. The outer zone is mainly confined between lines of force which approach the earth in the auroral zones, a result of much interest in connection with the origin of auroral and associated phenomena.

Realization of the association of the radiation belts with the earth's magnetic field drew attention to a calculation carried out as long ago as 1913 by Störmer. He was investigating the orbits of charged particles in the earth's magnetic field with a view to understanding auroral phenomena. Among the possible orbits he found certain types in which the particles are trapped. That is to say, they pursue a path swinging from one side to the other of a line of force until a point is reached at which the particle crosses the line of force normally. It can then proceed no further but retraces its path to a conjugate point symmetrically placed on the other side of the geomagnetic equatorial plane. Once more reversal occurs at this point and the same track is pursued back to the first extreme point and so on. This motion will continue indefinitely if the magnetic field remains constant in time and the particle is not disturbed by interaction with other particles. Given these possibilities it is natural to suppose that the radiation belts are built up through trapping of charged particles in these orbits. There will, however, be a gradual leakage through field fluctuations, arising from the ejection of plasma from the sun in which magnetic fields are " frozen " or through collisions. It is necessary, therefore, not only to verify that trapping can occur but also to identify the sources which maintain the concentration in each belt despite leakage.

The fact that charged particles may be trapped to form a radiation belt has been established by the largest scale experiment ever carried out, the so-called " Argus " experiment. Following a suggestion by Christophilos, charged particles were injected into the earth's magnetic field by high altitude explosion of an atom bomb of conventional type. The bomb was carried by a rocket up to a nominal altitude of 480 kms. above a point in the South Atlantic and detonated automatically. The firing location was chosen so that particles following a line of force would pass outside the more concentrated part of the inner zone and would be expected to return again to the atmosphere above the Azores Islands. Explorer IV was in orbit at the time with van Allen's counters in satisfactory operation. Three explosions took place and on all three occasions the counters in Explorer IV recorded the production of an artificial radiation belt of about 100 kms. thickness which could be detected clearly above the natural background for five days. It might be noted here that a belt is formed because the trapped orbits precess around the geomagnetic axis with a period of about 30/E minutes, where E is the energy of the particle in MeV. There is no doubt from these remarkable experiments that trapping does take place and information can be

obtained about the rate of loss, the probability of trapping, etc. It is suggested that future experiments might give even more definite interpretable information if the electron charges are injected from an electron accelerator carried in a satellite so that their energy distribution may be controlled.

There remains the question of the nature of the sources which maintain the two natural belts. Counters on Pioneer III, the American deep space probe which attained an apogee distance of 63,580 miles, recorded an intensity in the outer belt five times greater than observed from Pioneer I. During the latter launching the sun was quiescent but was strongly active when Pioneer III was launched. This suggests that the outer zone is replenished by the emission of corpuscular streams from the disturbed sun. It by no means follows that the inner zone is maintained in the same way. The "Argus" experiments produced very little disturbance of this zone, showing that it is very stable towards external influence.

The alternative suggestion for the inner zone is that it is maintained by secondary particles ejected outwards from the atmosphere through impact of primary cosmic rays. Neutrons with energies of several MeV, ejected backwards from atmospheric nuclei in such impacts, will eventually change into protons and electrons and it is considered that the trapping of these particles maintains the zone.

According to these interpretations the outer zone should only contain particles with energies up to 10^5 ev. or so whereas one would expect an appreciable proportion of relatively energetic particles (up to 100 MeV) in the inner zone. The data available on the energy distribution, from observations made from Sputnik III and the Russian deep space probes, do in fact reveal differences of this kind. Furthermore, Freden and White carried out an experiment in which nuclear-sensitive photographic emulsions were exposed at 1,000 miles altitude, in the inner zone, from a vertical sounding rocket and then recovered. Tracks of particles of the type expected were found on the developed emulsions.

Although much remains to be done to confirm the description of the zones and of their sizes, it is remarkable what a variety of the most highly developed techniques of space research have been employed. We might mention by way of conclusion that the Russians find no evidence of a radiation belt associated with the moon. This is consistent with the above interpretation and the evidence they find that the moon possesses no appreciable magnetic field.

ANALYSIS OF SATELLITES ORBITS AND THE FIGURE OF THE EARTH

It might be fitting to conclude by coming right back to earth again by mentioning what has already been achieved simply by analysis of accurate observations of the orbits of the first satellites. Whereas air resistance produces a gradual decrease in eccentricity and of period of revolution, the departure of the earth's gravitational field from that of a perfect sphere caures precessional motion of the orbit both about the earth's axis and in the plane of the orbit. It is therefore possible to disentangle the two sources of perturbation rather easily and work with secular effects. Not only has new and surprising information about air density been forthcoming but the ellipticity of the earth has been determined with greater accuracy than hitherto. Thus, if a and b are the equatorial and polar diameters respectively, the ratio $(a-b)/a$ is found to be $1/298{\cdot}2 \pm 0{\cdot}03$ instead of the previous value $1/297{\cdot}1$ derived from gravity survey. It has even been possible to determine the fourth harmonic in the harmonic expansion of the potential to an accuracy of 20% and to obtain evidence that an appreciable third harmonic is also present. The fact that these results have been obtained at such an early stage would hardly have been anticipated and shows how much can be obtained from good ground observations, even if one is unable to launch one's own satellites or even to obtain space for one's own instruments in satellites launched by someone else!

CONCLUDING REMARKS

The subject of space research is now so vast that it is impossible in this brief survey to do more than mention some of the salient features. These have been chosen to illustrate the wide range which is being covered to-day. At the present rate of development a similar article in a year's time would nevertheless include aspects not even mentioned above.

The Origins of Hydrostatics

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ALTHOUGH numerous problems on floating bodies had been set before his time, it was Archimedes (287-212 B.C.) who had no significant forerunner in the presentation of hydrostatics as a unified corpus of scientific knowledge. He presented a number of carefully reasoned arguments that in general resolved into the use of the principle which came to bear his name. Before Archimedes there had been some sound (and of course some quite unsound) mechanics, but little of a stature that remained acceptable by later standards. Archimedes' statics rests heavily on an empirical basis that he very fruitfully combined with theoretical concepts of equilibrium, gravity and fluidity in a manner that has recently been examined in relation to the elements of experimental physics.[9]

In spite of some random attempts to augment Archimedes' hydrostatics, it was not until the sixteenth century that any important developments occurred. Benedetti (1530-1590) made numerous contributions to mechanics and in discussing the behaviour of water in the tubes of a pump used in a fountain, came close to discovering the principle of the hydraulic press.

Simon Stevin (1548-1620) gave a correct idea of pressure, of its transmission, of its equal action in all directions and more particularly on oblique surfaces. The *Statics* of 1586 marks a very important step in the history of mechanics for in it Stevin imitated the axiomatic rigour of Archimedes in applications to both statics and hydrostatics. He proved the theorem about the force exerted by a fluid on a solid immersed in it in an original manner by use of the " principle of solidification " according to which a solid body of any shape and of the same density as a given fluid can remain in it at equilibrium whatever its position may be and without the pressures in the rest of the fluid being modified. He used this principle to determine the pressure on a given element of the base of a vessel by " solidifying " all the liquid except that in a narrow container whose base was the element being considered. Stevin showed that the pressure on the base depended only on the weight of the liquid in that " container " which must extend vertically from the base to the surface of the liquid. These considerations led to the statement of the " hydrostatic paradox " which Pascal considered and extended, viz. that a fluid, by means of its pressure, can exert a total force on the bottom of a vessel which can be considerably greater than the weight of the fluid contained in the vessel. Stevin showed that the force exerted by a fluid on the bottom of the containing vessel depended only on the size of the bottom surface and the height of the column of liquid above it and was not related to the shape of the vessel. This conclusion was demonstrated by an experimental procedure using different shaped vessels containing the same depth of liquid over bases of the same area. By means of such experiments Stevin observed how a small weight in a narrow tube could exert a very large pressure upon a plug in a wider tube so suggesting the principle upon which the invention of the hydraulic press was based. However, even with all these important theoretical developments, Stevin did not propose any idea of the utilization of pressure transmission in an hydraulic machine.

As in most other sciences[6], so in hydrostatics, Pascal as the alleged originator, had a number of significant precursors. Indeed, almost all that can be found in Pascal's hydrostatics can be found scattered and unconnected in numerous previous works. It was not that he discovered everything, but rather that he presented a coherent, ordered body of knowledge. Blaise Pascal (1623-1662) " distinguished himself from his contemporaries at once by the rigour of his experimental method, by the strict selection of his own principles, by the force of his dialectics in the polemics in which he had to defend himself, and, lastly, by his concern to propagate widely, in his time, a truth that was as yet known only to a few rare specialists."[1 p.200]

Pascal's system was developed in the two treatises published posthumously in 1663 and dealing with the equilibrium of liquids and the weight of the air respectively. In his treatise on liquids, Pascal connected the principle that came to bear his own name [2 p.112] with two principles of statics—that of virtual work and that of Torricelli on the descent of the centre of gravity. From such a starting point, Pascal established all the general theorems of hydrostatics, in particular Archimedes' principle and the principle of communicating vessels. The latter became the standard method of explanation of the hydraulic press for multiplying forces, a machine that did not, however, become a practical success until Bramah (1749-1814) found an effective way of packing pistons so as to prevent leakage past them.

Although Pascal's starting point of his hydrostatics was the principle of the hydraulic press combined with Torricelli's principle of the descent of the centre of gravity and the statical principle of virtual work, it is difficult to find any basis for such a combination. To some extent, Galileo had given the idea in a manuscript on hydrostatics published in Florence in 1612.[8] He employed velocity rather than distance, however, basing his considerations on the principle of virtual velocities and using " momento " as the product of force and velocity.[3 p.143] The contents of Galileo's treatise were both defended and attacked.[8] Mach's treatment of this topic is incomplete and misleading [2 p.65], for whilst Galileo's discussion of equilibrium in liquids shows an awareness of statical moments by

consideration of vertical distances, this is only a small and quite insignificant part of Galileo's hydrostatics.(3 p.143)

Leonardo da Vinci had been familiar with the concept of work (4 p.59) whilst Stevin quite clearly discussed the principle of virtual work.(3 p.127) Although his claim to priority is somewhat uncertain, Descartes placed this principle at the basis of statics by omitting reference to velocity and then vigorously defending his choice of distance.(3 p.156)

So in general, Pascal's immediate precursors would seem to have been Stevin and Benedetti in hydrostatics, Galileo for the relationship with statics and Torricelli and Descartes for the required principles of statics.

In his two treatises, Pascal not only unified the science of hydrostatics, but co-ordinated it with pneumatics which he showed could be presented so that the same general principles governed the behaviour of both gases and liquids. The statics of gaseous fluids had developed in connection with the two particular problems of the weight (or lack of it) of the air and the existence (or non-existence) of a vacuum. In spite of Simplicius' trenchant criticisms it had been the views of Aristotle that were quite firmly held for centuries since experiment had not yet been able to unequivocally resolve the issues involved. The first accurate attempts to determine the specific weight of the air were made in Italy by Cardan and Galileo, whilst in France the same problem was studied by Jean Rey (1576-1645) during the course of his chemical investigations.(1 p.201)

In correspondence with Mersenne, Rey formulated a correct view of atmospheric pressure by relating it to pressure in a liquid. About the same time Baliani in Italy and Beeckman in Holland propounded similar ideas and explained effects until then thought due to nature's *horror vacui*.(7) Galileo had already considered that nature's abhorrence might not be an absolute property of the world but was perhaps a definite force which could be measured. The triumph for the supporters of the view that air had weight and the atmosphere a pressure came with Torricelli's experiment. The interpretation offered as an hypothesis by Torricelli concerning atmospheric pressure in a "sea of air" was subsequently substantiated by Pascal, principally on the basis of the Puy-de-Dome barometric height experiment. He showed the identity of the concepts of the weight of the air and atmospheric pressure, maintaining that "nature has no horror of a vacuum, and that the heaviness of the mass of the air is the true cause of all the effects which have previously been attributed to this imaginary cause." (3 p.171)

Pascal's development of hydrostatics illustrates the use of deductive or geometrical-type reasoning. The works of Archimedes and Stevin read like textbooks of geometry and this procedure was continued by Pascal. The ideas of Archimedes came to be carried forward by those others who used deductive reasoning from postulates. The method depended on rigorous analysis and careful reasoning rather than on ingenious experimentation. Indeed in Pascal's treatises on hydrostatics and pneumatics it is quite impossible to tell which experiments were actually performed and which were only "thought" or "paper" experiments.

The history of the origins of hydrostatics presents a story of continuous evolution from Aristotle to Pascal with whom the knowledge assumed the form of a body of well-established principles. The seventeenth century continued to develop from Pascal's starting point with investigators such as Robert Boyle and Otto von Guericke. Subsequently Newtonian mechanics provided the basis for much of the eighteenth century development of the mathematical theory of hydrostatics with Bouguer, Maclaurin, Clairaut, Euler and d'Alembert. During the same century hydrostatics became a part of the analytical mechanics of Lagrange whilst finally in the early nineteenth century it was integrated with the general mechanics of Poisson.

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What Industry Requires from Non-Destructive Testing

[The summarized proceedings of the Institute's Non-Destructive Testing Group held on March 13, 1959]

For some time it has been realized that non-destructive testing should play an increasingly significant role in industrial processing, and that new and improved techniques and a wider and more comprehensive approach were required.

There is now a considerable measure of organized discussion and activity centring around various aspects of inspection, and the majority of persons in any way connected with the subject is catered for by one or more of the societies devoted wholly, or in part, to this subject.

However, tied as it is to industrial requirements, non-destructive testing can be of value only if its development is geared to the changing needs of industry as reflected in tighter inspection standards, the use of new and more exotic materials, and the introduction of automatic and more progressive manufacturing processes.

The link between managements who can appreciate these significant industrial trends, and those responsible for the development and advancement of inspection techniques, is perhaps the one that requires the greatest strengthening, and it was with this in mind that a discussion was arranged on the future requirements of industry during a course on non-destructive testing organized by the British Council in February, 1958.

Sufficient interest was shown by those attending the course to suggest that a follow-up meeting on a similar theme should be organized for a wider audience, and this was duly arranged by the Non-Destructive Testing Group of the Institute at The Institution of Electrical Engineers on March 13, 1959. It attracted an audience of about 250.

Dr. C. Sykes was Chairman of the meeting and he was introduced by the Chairman of the Group, Mr. B. R. Byrne.

The following is a summary of the contributions.

MR. B. R. BYRNE

There were obvious gaps, not only in the application of physics to non-destructive testing, but in the more fundamental aspects of the subject. Whilst the Non-Destructive Testing Group was interested primarily in physics, the problems could not be discussed without reference to instrumentation, and the Group was pleased to provide a platform for informed discussion, in the hope that sufficient material would be forthcoming to serve as a basis for subsequent action on the part of other bodies more directly concerned with such matters.

DR. C. SYKES

Those interested in the subject under discussion could be divided roughly into three groups. First, there were those who were actively engaged in either using or in developing practices of non-destructive testing, including the actual instrument makers. Secondly, there were those who were faced with certain problems of inspection which they felt were not capable of solution with present-day knowledge. Thirdly, there were the pure scientists who were or might be interested in providing the background knowledge which would ultimately enable some of the problems to be solved.

There were certain worthwhile results which might come out of the meeting. First, as Mr. Byrne had mentioned, there might be a list of major deficiencies in available techniques. There might be indications from the pure scientists of possible additional applications of existing knowledge. The instrument makers might be able to form conclusions as to the types of new instruments which were likely to cover important new needs of industry and possess the greatest versatility.

MR. A. BLACK (*Vickers-Armstrong Ltd.*)

The aircraft engineer was continually seeking stronger, lighter and still more reliable materials for use in structures of the highest efficiency on a weight/strength basis, combined with maximum reliability, and he needed means of measuring and testing non-destructively the effects of the conditions of service to which those materials were subjected in aircraft.

Ultrasonic Inspection

The aircraft industry was interested in being able to define much more closely the type of defect which gave rise to a particular kind of trace in order to set reliable standards. One fundamental difficulty was that the total reflecting area of the defect under the probe was measured and that discrimination between a large defect and a collection of small defects was difficult. Discrimination was also uncertain regarding the exact shape of the defect, i.e. the difference between a short wide one and a long narrow one.

It would be a big advantage to assess the soundness of intricate forgings before commencing expensive machining operations. Similar considerations applied to welding, particularly to fillet welds. Techniques were therefore required for dealing with complicated shapes while overcoming difficulties arising from the need for good surface coupling (rough surfaces) and for full exploration of the complete cross section, particularly with regard to defects immediately below the highly stressed surface.

Radiography

Aircraft firms used radiography for examining manufacturing materials, and also for components, mechanisms and complete structures, where visual examination was not possible.

They would welcome any improvement in sensitivity of the method to enable it to be more widely extended to wrought materials and in addition the introduction of lightweight and really portable apparatus, to enable very

short exposure times to be used. Some problems in both materials and structures could be solved if it were possible to produce X-ray or similar pictures of good definition, but magnified in size.

Electromagnetic Methods

The magnetic particle method, although widely used, required a good deal of care in the interpretation of results. Further development on the following lines was required:

(*a*) Developing fluids. A series of fluids which would discriminate between various types of surface defect and define their depth.

(*b*) Automation. A method of signalling the change in the surface magnetic field, so that only defective parts need be examined visually in a production run.

(*c*) Penetration. The development of methods of signalling the effect of internal defects on the magnetic field.

Unsolved Problems

(*a*) *Fatigue of Structures*

It was well known that, owing to the variables which existed in service conditions, and in particular in the weather conditions through which an aircraft might fly, similar structures would produce widely different fatigue lives as defined by hours flown. The expense of testing a number of aircraft of a given type under such conditions in order to establish the fatigue life under varying combinations of repeated load was prohibitive. Although recordings were taken of the frequency and total number of high loadings experienced, this did not provide the complete picture. It was, therefore, necessary to apply a scatter factor and to limit the acceptable life of the structure to a figure known to be much less than its average life.

New non-destructive test procedures which produced the following information would enable a radical change to be made in the approach to this problem The first fact required was to what extent the total fatigue life of a given structure or component had been used up, and the second at what precise stage a fatigue failure, however minute, had occurred. No progress had been made with the first requirement but the detection of fatigue failures at the earliest possible stage was so far being dealt with by means of X-rays. The previous comments on the present limitations of the process for material inspection applied equally here, and there was a great need for an infallible structural crack detector.

(*b*) *Stress Corrosion*

A further big problem in aircraft construction at the present time was the susceptibility of certain high-strength light alloys to stress corrosion. It had been established that certain batches of these materials would fail by intercrystalline cracking when subjected to a steady static stress in a direction transverse to the grain in the presence of corrosive conditions which need be only of a very mild nature. The time to failure had been found to increase with decrease in applied stress, but failure could occur at stresses well below the normal elastic limit of the material. The materials concerned were the aluminium-magnesium-zinc alloys which gave the highest strength/weight ratio and which, apart from this problem, were excellent materials.

The problem was being investigated at high pressure and it was certainly hoped by manufacturers that material of this type which was not susceptible to this trouble would eventually be available. In the meantime, a non-destructive method of distinguishing between susceptible and non-susceptible batches would enable the hazard which undoubtedly existed to be eliminated together with the costly precautionary processes which were at present essential when these materials were used.

(*c*) *Internal Stresses*

Stresses caused by quenching during heat treatment were always undesirable, and in the case of large forgings might be disastrous. Methods existed for measuring such stresses. It would be of great advantage to be able to measure and define in a non-destructive manner the level and distribution of internal stress throughout the mass both of the original forging and of the finished machined part.

(*d*) *Sandwich Construction*

A new problem now arising stemmed from the development of what was known as sandwich construction. Thin sheets were separated by core material which might be honeycomb section or other lightweight structures on edge. To develop the full strength it was essential that a continuous bond should exist between core and facing. A rapid method for a complete survey of each piece which might be extremely complicated in shape, after bonding was required. The materials concerned might be light alloy, stainless steel, titanium, molybdenum, or reinforced plastics, and the bonding could be carried out by such a process as brazing or by the use of a synthetic resin adhesive. X-ray examination had been used and also mechanical proof testing, but these methods were expensive and time-consuming and not entirely successful.

(*e*) *Strain Recording*

The last unsolved problem which there was time to consider was that of measuring and recording the stresses induced in aircraft structures in flight. Although experience and investigations, coupled with increasing knowledge of the materials in use, enabled the aeronautical engineer to predict the stresses to be withstood, there remained an appreciable degree of refinement which could be achieved if precise information became available. The use of strain gauges enabled working stresses to be defined within the limits of being able to apply such gauges to a surface which was accessible for the purpose. It would be a great step forward if the stress pattern, and particularly the stress concentrations throughout a component or a structure, could be measured and recorded in flight by some simple means.

MR. E. W. COLBECK (*Hadfields Ltd.*)

At the earlier British Council meeting a number of the partcipants had expressed very strongly the view that there was no satisfactory mechanism for bringing together the various interests in this country concerned with non-destructive testing, and that there was perhaps no satisfactory medium for financing the research work

which was necessary. It had even been suggested that a research group might be formed in which, of course, the users and the instrument makers would both play a part.

The Steel Industry was neither dissatisfied with, nor complacent about, the present state of affairs. A good liaison existed between the instrument makers and the industrial concerns. The representatives of the instrument makers appreciated the importance of coming to see for themselves the problems on the shop floor. However, like others concerned with making a profit, they usually required a steady and continuous production run. Unfortunately, many non-destructive testing requirements were very specific. He suggested that such problems were best solved by the people on the spot, probably using home-made apparatus.

He felt that Research Associations could not only provide a useful link between scientific bodies and actual or potential users of new tools and techniques, but by getting together among themselves could do useful work. A number of Research Associations were interested and there was already excellent liaison between them on common problems.

The title of the present meeting used the word " Industry " and not " Research," so that it was necessary to point out that Industry needed robust tools to withstand workshop conditions. Further, such tools must be mobile. It was worth calling attention to one fact of practical importance. Any new tool which was invented should be capable of operation by a normally intelligent labourer, and should not require a first-class Honours man to operate it.

Ultrasonics

The time taken to examine a large forging or plate was excessive. He felt very sorry for the consortia dealing with the new nuclear power stations, who had to achieve 100% coverage on site examinations. Much more rapid coverage of large areas was required. There was also a need for improvement of examining very rough surfaces, because despite advances in immersion technique it was occasionally necessary, and a great nuisance, to plane a path down the whole length of a forging to produce a reasonably satisfactory test surface.

With regard to interpretation, one could cite many cases of dispute, and there was often grave doubt as to the meaning of a particular oscillograph trace. They wanted something which would give a clear two-dimensional picture of what was seen, something to take the place of the trace on the oscillograph screen. If they could have something quite simple which could be translated into three dimensions it would mean a considerable advance.

Radiography

Here the same criticisms applied in regard to interpretation as in the case of ultrasonics. Better means were required for examining dense materials and very thick sections. The new isotopes appeared to be limited to thicknesses of 4 in. or 5 in. Thicker sections presented real difficulties. Was there any hope of devising something less expensive and much more mobile than the costly betatrons and linear accelerators proposed for the examination of massive sections ?

Mr. Colbeck made a plea for assistance in the application of simple long-established methods, such as the etching and pickling of castings, which were excellent methods for finding surface defects.

Liquid Penetrants

Austenitic steel surfaces, because they were non-magnetic, presented difficulties. There was often difficulty in deciding whether a crack was present or not, e.g. in the case of steels of coarse and medium grain size it was difficult to decide whether the effect observed was a discontinuity at a grain boundary or not.

Would it be possible to devise a method based on obtaining electro-chemical prints of the surface ? Where there was a discontinuity it would show up quite simply, and one would get, as with a sulphur print, a mark which would indicate the defect.

Outstanding Problem

Was it possible to find defects in a hot object, such as a large ingot ? Flaws did admittedly close up in forging, provided they were clean, but in view of the cost of machining, for example, a rotor forging, which might afterwards be found defective, it would be very useful to have some method of examining hot objects. Moreover, knowledge would be greatly increased thereby.

MR. R. D. HAMER (*Aluminium Laboratories Ltd.*)

In the notice of the present meeting automation was mentioned. About a dozen companies in this country produced a wide range of wrought aluminium forms sharing an annual production of about 250,000 tons. Only a few had semi-continuous operation resembling to some extent the large continuous mills of the U.S.A. A very substantial expansion was to be expected in the next ten years, but this expansion would be poorly conceived unless a more scientific approach to the operations of the industry was established well in advance.

The means to inspect non-destructively and subsequently to control quality factors in aluminium products were lacking to a high degree. In many cases it was probably not practicable or desirable to automate any part of these processes, but there was a pressing need for reliable instrumentation, easy to use and capable of linkage with some automatic control system. Rapid methods were needed for quality control as early in the production cycle as possible. Material was too often rejected in the final stages and unsatisfactory material was supplied more often than one would like to see it.

A very large percentage of the aluminium materials used to-day was cast by the semi-continuous direct chill process. At this significant stage in the fabrication of an aluminium product, when the molten metal had been converted to solid form, the best opportunity was presented to ensure either that the product would be satisfactory metallurgically or that the ingot could be scrapped at a time when the least possible expense had been incurred. At present, when materials for important applications were involved, billets were inspected by an expensive and somewhat cumbersome ultrasonic testing technique to determine whether or not they contained such obvious defects as inclusions, holes or cracks. The casting process was still largely

dependent on skill and the many variables involved were not accurately controlled, so that there was no assurance that the metallurgical quality of any one billet would necessarily be well suited for the final product for which it was intended. It would be of the greatest possible assistance to the aluminium industry if equipment were available to enable the operator to distinguish at this stage whether or not the billet which was being produced was of satisfactory metallurgical quality.

Inspection equipment was also highly desirable for later stages in the fabricating procedure, where hot and cold work and heat treatment had had their effects on the metallurgical condition. Complete continuous automatic examination for defects and for physical and metallurgical properties during critical operating stages would permit rapid and possibly automatic correction of faulty operation. This would lead to very great savings in production costs and substantial improvement in properties.

The consumer demand for flatness had become increasingly exacting, and the development of instruments for measuring flatness and equipment for correcting errors of flatness required early attention. A continuous determination of the temperature of rapidly moving material was still a very uncertain operation.

He had studied with interest the summary of the activities of the D.S.I.R. establishments,* and he had some knowledge of similar activities in other institutions. It was not encouraging to find that very little of the work they were doing was closely applicable in the aluminium industry.

The widespread dispersion of fundamental and applied research and instrument development suggested that expert co-ordination of the research and concentration of the final development effort were critical necessities. A great deal of scientific time and money would be wasted unless the means were established to co-ordinate results and put them to work. The solution did not necessarily involve the establishment of an independent new research and development organization, but required the delegation of responsibility to the best and most appropriately equipped existing organization, or possibly two organizations. He did not believe that a Government establishment could do the job; the organization must be very close to industry, and, to his somewhat limited knowledge, only the British Non-Ferrous Metals Research Association and British Iron and Steel Research Association qualified. Either or both could set up an integrated department capable of doing the necessary job to meet the needs of all the metal industries. The size of the group and the rate of progress could be readily determined by the amount of money which the industry would subscribe as a result of the project being properly conceived and presented.

The situation demanded the provision of an authoritative, active and integrated organization, solidly supported by industry. The formation and maintenance of a suitable body would cost industry only a small fraction of the savings which could be readily foreseen.

MR. W. C. F. HESSENBERG

(British Iron and Steel Research Association)

In the part of the steel industry which dealt with general purpose and very large tonnages, the tendency was towards greater continuity in production methods and the urgent need was for methods of inspection " on the run."

One of the basic problems of doing this was to achieve coupling between fast moving material and inspection instruments. Some success had been achieved with mechanical couplings but it was only since X-ray and isotope gauges had become available that it had been possible to monitor continuously the gauging of material such as hop strip. These radiation gauges, however, were not applicable to great widths or heavy masses.

It would be appreciated that if such an elementary property as dimension presented inspection difficulties, how much greater were the difficulties of measuring surface finish and finding interior structural faults. Even when such difficulties were overcome there would remain the further difficulty that information would be recorded at a very high rate and there was little time to assess it and take decisions. Instruments developed for continuous inspection would almost certainly have to work in conjunction with information handling equipment of a very advanced kind and in some cases with automatic process control. These facilities would in turn involve the drafting of codes of acceptance. Before it was possible to design an automatic system the meaning of " good " and " bad " must be put into communicable form.

Research associations had a role to play in these matters. They offered economy of effort through co-operation and closeness of contact with industry. However, the final stages of development must always be worked out between user and supplier who must in the end come together and thoroughly understand each other's needs.

GENERAL DISCUSSION

DR. R. F. HANSTOCK

(U.K. Atomic Energy Authority)

Dr. Hanstock expressing his personal opinions said that it seemed reasonable that when an atomic power station was being built, involving the construction of a pressure vessel which, once put into operation, was unlikely to be accessible for complete inspection for the whole of its lifetime, it should be regarded as essential that the standards of inspection applied to it during the manufacture of the material and the actual construction of the vessel should be exceptionally high, probably higher than had been applied in any other case than that of aircraft construction. Those two fields of construction were roughly similar in this respect, that the consequences of failure were extremely serious.

He thought that so far as the inspection of thick steel plate was concerned the most promising method for thickness above 4 inches was ultrasonic echo-sounding and this could be applied to the examination of welds. Its development would involve a much more elaborate technique than was at present conventionally used, in order to be able to assess the magnitude and also the significance of such defects as might be found. At the same time such inspection would have to be speeded up by some degree of automation.

* Summary available on loan from Secretary, N.D.T. Group.

MR. H. W. TAYLOR (*Kelvin Hughes Ltd.*)

Mr. Black had referred to sandwich construction. It was possible at the present time to inspect for good or bad bonding but not yet possible to assess the bond in the intermediate stages of quality.

A considerable amount of work had been done on inspection of steel plate at high speed. A single ultrasonic unit would inspect steel plate at up to 100 sq. ft. per minute and maintain a constant sensitivity of inspection together with a permanent recording. There was an automatic indication if the system failed. The speed of inspection could naturally be increased by multiplying the number of channels in use.

With regard to large rotor forgings and other components where information was required about the interior, the surface must afford a reasonable chance for the laws of physics to be applied.

MR. G. BRADFIELD
(*National Physical Laboratory*)

Within the field allotted to them the N.P.L. tried to foresee what industry might need in the way of development and had linked this to the more fundamental side of physics. He then showed slides illustrating some of the more fundamental work they had been doing such as:

1. System developed for producing flaws of various sizes and shapes in solid blocks of metal so as to be able to evaluate their response to ultrasonic echo-sounding.
2. Special surface wave probes.
3. Measurement of surface texture by reflection of surface waves.
4. A device providing information on relative hardness and grain size of materials.
5. Magnetostriction devices for measurement of the modulus of rigidity of a rotating shaft.
6. A steerable beam device for precision scanning of very large forgings such as rotors.
7. Variable frequency probe for discrimination of size, shape, and attitude of a flaw.

Mr. Bradfield concluded his remarks by describing briefly the testing of a small disc for cracks which were only 1/32 inch below the surface using a shear wave technique.

DR. C. SYKES

Dr. Sykes intervened to suggest that the job of the instrument maker ought not to be made too difficult. A good deal had been said about the time that it took to examine a rotor shaft. A really big rotor shaft was worth about £30,000 and took eight months to make, so that whether it took 2 hours or 3½ hours to test it ultrasonically was of no importance so far as that job was concerned.

MR. W. G. COOK (*Rolls Royce Ltd.*)

There were many different interpretations of what constituted a significant crack and there was need for an instrument to indicate crack depth. Sometimes the only way to decide whether a part should be scrapped or not was to dress the surface and repeat the tests. If the crack disappeared before the minimum dimension was reached the part could be accepted. There were some useful electrical resistance methods for cracks in purely symmetrical shapes, but they were difficult to use on the complicated shapes found in aircraft work.

Mr. Colbeck had mentioned the use of etching. There seemed to be a very urgent need for an etch which contained a trace element, so that after etching one could do the equivalent of a penetrant check and have a fluorescent or colour etch. On aluminium it was possible to use chromic acid anodizing in a limited way, but an etch combined with the property of the standard fluorescent paint would be very valuable.

There were two problems outstanding with regard to creep; one was to assess creep non-destructively and the second was to assess at a given life how much was left. The second might be easier to solve. Since it was not a micro-effect, such as fatigue in its initial stages, neither so localized, it should be a more promising problem to solve.

Automation of inspection was of value because of the speed which it made possible but in the case of critical components the main worry was the reliability. Despite advances in mass production, mechanical handling and so on, non-destructive testing was still largely geared to one pair of eyes. Automation which could overcome the unreliability of a pair of eyes would be worthwhile, not necessarily for greater speed but for greater safety. Here he was not referring to statistical sampling but to conditions where one had to be sure the component was just right.

Mr. Colbeck had asked for apparatus that could be used by a labourer. So far as the aircraft industry was concerned Mr. Cook was convinced that unless a larger proportion of talent was employed in the workshops not only on testing but on operational research this country would lag behind the Americans who, by maintaining a better balance in this respect, produced a good article more cheaply despite labour costs three times those prevailing here.

While there was a need for instruments which could be used easily, skilled people were needed to make proper assessments and the management must see that the right people were available to get the information and to use it once obtained.

MR. D. O. SPROULE (*Consultant*)

Previous speakers had mentioned enough different development projects to keep those who were interested in non-destructive testing busy for the remainder of their lives without solving all the problems. It would therefore be necessary to make a selection and one thing which would help a great deal would be if industry would make up its mind, in the many cases in which it did not know already, just what did matter. It was discouraging when one had found a flaw without being able to say how big it was or at what angle it lay until one had spent some time examining it, to be told that it did not matter because the user did not know whether that kind of flaw was critical or not. In other words, if industry knew what was required of it this could make all the difference between years of unsuccessful work and perhaps a few months of successful and satisfactory work.

Reference had been made to the importance of being able to inspect material before it was cold. He too supported the plea for testing at an early stage. Inclusions and holes could be found ultrasonically while metal was solidifying.

MR. S. CARLISLE
(*British Iron and Steel Research Association*)

One of B.I.S.R.A.'s big problems was that of getting new instruments which they had developed in the laboratory properly engineered so that they became a working proposition in production.

He showed on a slide the essential processes from the conception to the ultimate development of the type of instrument in question, commencing with information on available instruments, on the problem so far as it concerned the process and on the relevant physical principles of measurement. From the second stage where development of suitable measuring or inspection techniques took place they proceeded to the third stage of getting the instruments into a suitable form for integration with the plant. He suggested that the first stage was primarily the job of research in the laboratories associated with instrument users. The second stage was a function of the instrument industry with support from industrial research associations and perhaps from a research association of their own. The third stage was rather different and he would suggest that this third function could best be fulfilled by plant builders who should in his view take a greater share in the work and give more encouragement and assistance in the development of instruments which were to be intimately associated with their plant.

There were several reasons why the foregoing system ought to work and one of them was that many such instruments were very specific and were required only in small numbers but the cost of development might be high and the plant builder should be interested in making available money for development which would probably be only a very small proportion of the plant cost.

It seemed likely that in the future a plant builder who could offer a complete inspection technology with his plant would be in a better position to sell it than one who could not.

REPRESENTATIVE OF TEMPLEBOROUGH ROLLING MILLS

The wire industry was constantly demanding better wire rod quality. Modern methods of drawing and coiling made tremendous demands on the wire and the wire drawer could not tolerate even small amounts of sulphur or carbon segregation or pipe. Pipe was relatively easy to find but could ultrasonic flaw detectors be developed to find segregation ? At present his firm had to test by hand something like 30 per cent of their total output.

Rolling laps as small as 0·01 in. in 5-gauge rod caused trouble for certain applications. An instrument which could detect these laps, particularly if it could be connected with the mill screwdowns, so that the stock could be continuously adjusted if laps were found while the mill was rolling would make it possible to produce steel of highest quality. An instrument was also required for gauging the size of wire rod from 3/16 to 9/16 in. diameter without requiring the wire to be held steady. Wire must be coiled on long reels and if held too steady it would not go onto the reel.

DR. R. K. BARNES (*D.S.I.R.*)

Dr. Barnes referred to the gauging of the width of steel strip. He thought that this was possible by radioactive gauging using a beta-particle emitter shaped as a long strip and placed at right angles to the direction of travel of the strip through the mill. Above this there would be a detector giving readings proportional to the amount of the beta-particle emitter which had remained uncovered.

DR. E. G. STANFORD
(*Aluminium Laboratories Ltd.*)

Dr. Stanford had asked to speak because he did not see where the discussion was leading them. Many speakers were thinking in terms of defect detection which was understandable from the general engineering point of view, but the physicist was concerned with the quality and to him flaws were just one aspect of non-destructive testing.

The object of the Institute of Physics Group was to see to it that the background scientific knowledge was continually fed to technologists, providing them with the data required for the solution of problems associated with the progress of industry such as automation and one hundred per cent inspection for aircraft and automobile engineering.

The physicist could measure the characteristics of materials in terms of physical properties and do so non-destructively. Unfortunately the determination of mechanical properties almost always called for a destructive test. The two were linked by the structure of the material itself and it was necessary to know the relationship between structure and physical properties, structure and mechanical properties, and also that between mechanical properties and physical properties. Work to this end was going on in universities and elsewhere and the physicist in industry must study this fundamental work. How should fundamental information be obtained from all these research groups for effective use in industry ? That was the problem with which the Non-Destructive Group was concerned at the moment. They had to make clear to those engaged in such work just how their efforts could best be applied. How was the Group to get information which existed in this country but which was not being used effectively at the present time ?

MR. BOXALL
(*British Non-Ferrous Metals Research Association*)

Work was at present going on to develop an X-ray micro analyser with funds coming in part from research associations working together. Another example of collaboration was a symposium prepared for May, 1959, when they would discuss X-ray fluorescence analysis.

The research associations had a part to play in assessing the demand for instruments together with the background information which they could pass on to the instrument manufacturers. This of course was in addition to fundamental work where no other organization was available.

MR. B. R. BYRNE (*British Railways*)

In speaking of the possibilities of testing glued assemblies Mr. H. W. Taylor had doubtless in mind the pulse-echo or transmission ultrasonic methods. It might be timely to mention recent work done in Amsterdam by

Schijve and published by the Dutch Royal Aeronautical Laboratory.

Schijve treated the two glued members as masses joined by a massless spring. He had attacked the problem first from the theoretical standpoint and had written down the equations of motion. He claimed that his experimental results were in good agreement with theory. Apart from the fundamental frequency of the assembly there was another more prominent and lower frequency which was characteristic of the bond and this was the parameter by which the bond was judged.

Mr. Byrne also referred to the report of the International Conference on Non-Destructive Testing in Brussels in 1955 which contained an account of the use of the Savart pendulum as a means of testing the vibrational characteristics of supposedly identical assemblies.

MR. D. F. LEACH
(*British Jute Trade Research Association*)

Mr. Leach came from the jute industry. The meeting had given him the impression that a large proportion of industry in this country was like the jute industry, which was an old one, not using refined techniques. He thought it would be a waste of time and effort to investigate new principles. There would be little chance of applying them at present and there was still too much information which had been known for a long time which required application.

Research associations such as the British jute trade research association were able within their limited resources to develop instruments, but there were difficulties in getting them manufactured satisfactorily and in getting them marketed. Makers were prepared to produce instruments if research associations were prepared to instal them and see to their running. Many research associations were too small to deal with such problems.

DR. A. NEMET (*Consultant*)

It was a mistake to believe that problems would be solved by clever physicists and engineers banded together in a new research association or an extension of two old research associations. It was the feeling of the instrument industry that about four fifths of the expenditure and effort required to produce a workable instrument must be incurred after the physicist and the engineer had dealt with fundamental considerations, and when engineering development was what was required.

How could laggard and reluctant industry be persuaded to take more interest in the matter ? He suggested that specifications should be collected from user industries, worked out in collaboration with users and then circulated to the instrument industry together with an estimate of the market. The exchange of information should be more regular. There should be a single (English) non-destructive testing journal in which to look for new contributions instead of having to search in fifty different journals.

MR. L. H. WELLS (*Ultrasonoscope Co. Ltd.*)

In a field where the instrument made did not sell in large quantities a problem was that every manufacturer who came to them wanted something different. There was also the question of acceptance standards. Because an instrument maker developed an instrument which would detect a very small defect the buyer was inclined to think that this was what he wanted and then the steel makers, say, were expected to work to this requirement. The position would be eased if agreement could be reached between steel makers, users and instrument makers on a specification.

He had heard that standards regarding the lamination of steel plate were under discussion—but with whom ? If standards were less exacting, simpler and more reliable instruments would be possible. The same applied to welding. Some customers could persuade the insurance companies to accept the results of ultrasonic testing and others could not. Where did this question stand and what should instrument makers spend their money on developing ?

MR. E. SMITH

Quite a number of methods are now available for bonding natural and synthetic rubbers to metals and their introduction has led to the increasing use of bonded rubber components for anti-vibration mountings, flexible couplings, shock absorbers, etc., many in key parts of industrial equipments.

The usual inspection applied is the overload test but this is far from satisfactory as a routine method. Ultrasonic techniques have been tried but, whilst successfully detecting voids, give no indication of bond strength if the components are in intimate contact.

As the use of this type of joint is likely to extend, some more reliable inspection technique should be developed.

MR. F. C. BIRD (*Walter Somers Ltd.*)

The main difficulties of ultrasonic inspection were the formulation of specifications and the associated problems of interpretation in the light of the variable results obtained from different makes of instruments. This could lead to difficulties as between purchaser and supplier, who might even be thousands of miles apart !

Some of the obvious practical problems upon which more quantitative information was desirable were:—

1. The influence of scale as regards thickness and adherence.
2. The relative efficiencies of coupling media.
3. The limitations imposed by rough surfaces.
4. The optimum conditions as regards wave frequency, pulse frequency, crystal size, beam spread, etc., in the examination of cast structures such as large ingots, together with the present practical limits and future prospects of this application.
   The size and type of internal defect which can be estimated with reasonable certainty, and the extent to which reliance has still to be placed upon personal experience as compared with the reduced degree of guess work which improved instrumentation might provide. It may be that even after thorough investigation this application may have inherent limitations.
5. The application of automatic or semi-automatic devices which will compensate, within limits, for the variations in surface contact and provide a visible or audible warning when a pre-set standard of acceptable defect has been exceeded.

The aim should be towards such correlation as would enable a purchaser to specify, and a supplier to guarantee that products comply with some generally recognized standard. This was easy to state, but the difficulties were immense and formed the real crux of the problem.

DR. C. SYKES

The emphasis that afternoon on the use of non-destructive testing seemed to have been purely from the point of view of inspection and from the point of view of making sure that what the customer got was sound. Those were two very desirable results of non-destructive testing, but the most important thing of all which was obtained from it was the knowledge which enabled the manufacturer to improve his processes. For example in the days before ultrasonic instruments were available it had not been possible to tell whether forgings had internal cracks or not, nor could one find out whether any change which had been made in the manufacturing process was affecting the quality of the forgings. As soon as an ultrasonic instrument became available one could start to investigate all the variables which led to the production of cracks. Taking that to its conclusion, there would eventually be no need for ultrasonic inspection, because if the process was right there would be no defects to inspect. There could be no doubt, therefore, that one of the principal reasons for pushing ahead with non-destructive testing was to make it possible to carry out research on processes.

A good deal had been said about the cost of instruments and the fact that people could not afford them. It might be desirable to emphasize that no part of industry was characterized by philanthropy. The instrument maker had to live, and if the user could not justify, by the improvements obtained from using an instrument, the expenditure on it, it was not worth buying. The cost of developing the instruments which had been mentioned would have to be provided by industry, and if industry was not prepared to foot the bill it would not get the instruments.

It seemed that many of the instruments which did not exist but which people said were necessary were not available because the fundamental physical background was not there. There was a number of pure physicists present (as distinct from applied physicists) but they had not said a great deal. Probably one of the difficulties was that almost every property in which an industrialist was interested was what the pure physicist called a structure-sensitive property. The only thing that the physicist could measure accurately was a structure-*in*sensitive property. In that lay one of the great difficulties in developing non-destructive tesing methods.

The Chairman and several members of the British National Committee for Non-Destructive Testing were present at the meeting and, as a result of conversations which took place afterwards, the whole matter was discussed at the next meeting of the National Committee. It was realized that, although the discussion of March 13 had drawn attention to some definite needs, a more specific attack on the problem was wanted if those needs were to be defined in precise terms.

The National Committee, therefore, felt encouraged to set up a Working Party consisting of Dr. E. G. Stanford (Chairman), Mr. C. G. Garton and Mr. C. E. Phillips to investigate in detail the needs of industry. This working party has since been augmented by Mr. G. B. Thomas who is conducting a similar investigation for the Ministry of Supply Inspectorates.

This Working Party has already met on a number of occasions and has begun to invite representatives from particular industries which have an interest in non-destructive testing techniques. As a start, they have met representatives of the power generation industry and hope soon to ask the aircraft industry to submit evidence. Their present plan is to collect a reasonably wide range of comments and then to analyse them. It is expected that a number of subjects needing investigation will be high-lighted by the discussions which are taking place and that some of these can then be worked upon by interested research organizations. As an interesting by-product of the Working Party's efforts, it has already been able to suggest solutions to certain detail problems by reference to existing knowledge.

Notes and News

New Year Honours list

The following members received honours in the New Year Honours list :

C.B.E. F. I. G. Rawlins (*Fellow*)
O.B.E. G. E. Bell (*Associate*)
J. S. Hales (*Associate*)

Mr. G. R. Crowe

Many members will know, or know of, Mr. G. R. Crowe, laboratory steward of the Cavendish Laboratory, Cambridge, and will have been very pleased to learn that the university has conferred on him an honorary degree of M.A. Sir George Thomson wrote to congratulate Mr. Crowe on behalf of the Board in the following letter.

" The Board of The Institute of Physics have given me the very agreeable task of writing to congratulate you on your honorary M.A. Few awards have given more general pleasure to physicists. So many of us know the merits of your work from personal experience, and physicists without exception know the work to which you contributed so much.

I am very proud of the fact that I was the first, or one of the first, whom you ever helped in this way—I think even before you started working for Rutherford, if only by a matter of days.

Everyone who has worked in a physical laboratory knows the importance of the work which people such as you are doing ; it is too seldom that we have an opportunity of expressing this. I am sure that the Board is glad of this honour, partly because it is one of the rare occasions on which they can pay tribute to this class of men to whom they owe so much, and whose work has contributed so greatly to the advancement of physics, though seldom indeed to the extent which yours has."

Mr. G. R. Crowe.

With acknowledgment to the Educational Foundation for Visual Aids. A still from the film "Conquest of the Atom."

British Nuclear Energy Conference

The British Nuclear Energy Conference was established in 1955 by The Institutions of Civil, Mechanical, Electrical and Chemical Engineers and The Institute of Physics. It is a collaborating and co-ordinating body whose object is the advancement and dissemination of knowledge covering the applications of nuclear energy and ancillary subjects.

Members of any of the constituent societies (now increased to twelve) may attend meetings on nuclear energy arranged by any of the other bodies.

The Conference publishes the *Journal of the B.N.E.C.* four times a year. It contains papers presented and discussions arising at meetings of the Conference and of the constituent societies and attempts to provide a record of the most significant developments in the field of nuclear energy.

The *Journal of the B.N.E.C.* is available for sale to the general public but preferential rates of subscription (30s. post free—single copies 7s. 6d. each) apply to members of the constituent societies.

The constituent societies are : The Institution of Civil Engineers, The Institution of Mechanical Engineers, The Institution of Electrical Engineers, The Institute of Physics, The Institution of Chemical Engineers, The Institute of Metals, The Iron and Steel Institute, The Institute of Fuel, and The Joint Panel on Nuclear Marine Propulsion (comprising The Institute of Marine Engineers, The Institution of Naval Architects, The Institution of Engineers and Shipbuilders in Scotland, and The North East Coast Institution of Engineers and Shipbuilders).

High Speed Photography

The Society of Motion Picture and Television Engineers is organizing the 5th International Congress on High Speed Photography to be held in Washington, D.C., from October 16 to October 22, 1960. Intending authors should present their papers through their national delegate. The British delegate is Dr. R. F. Saxe, Hon. Secretary, National Committee for High Speed Photography, Queen Mary College, Mile End Road, London, E.1, who will be pleased to receive notice of suggested contributions and from whom " Preliminary Forms for Authors " are available. Summaries must be received by February 16, abstracts by May 16 and manuscripts by July 16.

American symposium on molecular structure and spectroscopy

The Symposium on Molecular Structure and Spectroscopy will be held at the Department of Physics and

Astronomy, The Ohio State University, this year from June 13 to June 17, 1960. There will be discussions of the interpretation of molecular spectroscopic data as well as methods for obtaining such data. In addition, there will be sessions devoted to those phases of spectroscopy of current interest. A dormitory will be available for those who wish to reside on the campus during the meeting. For further information, or for a copy of the program when it becomes available, members should write to Professor R. A. Oetjen, Department of Physics and Astronomy, The Ohio State University, Columbus 10, Ohio.

Crystal Structure Determination

The University of Manchester Extra-Mural Department (on behalf of the Department of Physics of the Manchester College of Science and Technology) is organizing a Summer School in Modern Methods of Crystal-Structure Determination. This will be held from August 29 to September 9, 1960, after the Cambridge Meeting of the International Union of Crystallography. The School will be held in the College of Science and Technology. Visitors will be lodged at one of the University Halls of Residence. The course will be suitable for those who already have some experience in the subject and who wish to extend their knowledge. The charge for the two weeks tuition will be £5. Board and Lodging, for those who require it, will be about £20. NATO has given a generous grant from which substantial travel and subsistence allowances can be made. Inquiries should be addressed to Professor H. Lipson, Manchester College of Science and Technology, Sackville Street, Manchester 1.

Forthcoming Institute Meetings

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Feb. 11	**Liverpool** The University	Dr. L. L. Green (*University of Liverpool*)	**Nuclear models**	7.00 p.m.	Liverpool and North Wales
Feb. 12	**London** The Institute's House	Dr. J. Ring (*University of Manchester*) Dr. H. A. Gebbie (*National Physical Laboratory, Teddington*)	**Interferometric spectroscopy**	3.00 p.m.	Applied Spectroscopy
Feb. 12	**Swansea** University College	Dr. H. T. Miles, Grad.Inst.P. (*Associated Electrical Industries Ltd.*)	**The physics of fully ionized gases**	5.15 p.m.	South Wales
Feb. 15	**Manchester** The University	Mr. J. G. Crowther	Branch Annual General Meeting followed by a lecture on **The history of science in Manchester**	6.30 p.m. 7.00 p.m.	Manchester and District
Feb. 16	**Birmingham** Exchange and Engineering Centre	Dr. J. W. Glen (*University of Birmingham*)	**Physics of glaciers**	6.30 p.m.	Midland
Feb. 17	**London** The Institute's House	Professor S. Tolansky, F.Inst.P., F.R.S. (*Royal Holloway College, Egham, Surrey*)	Branch Annual General Meeting followed by a lecture on **The microstructures of surfaces**	6.00 p.m.	London and Home Counties
Feb. 17	**Harmondsworth** The Road Research Laboratory	Mr. N. W. Lister (*Soils section*) Mr. J. J. Trott, A.Inst.P. (*Special problems section*)	Visit to the Road Research Laboratory, Harmondsworth, Middlesex. Two short papers will be presented followed by a tour of the laboratories. The number for this visit is strictly limited.	2.00 p.m.	Stress Analysis
Feb. 19	**Gloucester** Technical College	Dr. A. B. D. Cassie, C.B.E., F.Inst.P. (*Wool Industries Research Association, Leeds*)	**Physics of clothing**	7.00 p.m.	South-Western
Feb. 19	**London** The Institute's House	Dr. P. Schagen (*Mullard Research Laboratories*)	**Electroluminescent image intensifiers**	6.00 p.m.	Non-Destructive Testing
Feb. 23	**London** The Institute's House	Dr. W. M. Lomer (*Atomic Energy Research Establishment, Harwell*)	**Magnetic properties of alloys**	5.30 p.m.	Electronics

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Feb. 24	**Dundee** Queen's College	Professor J. C. Gunn (*University of Glasgow*)	**Parity non-conservation**	5.30 p.m.	Scottish
Mar. 2	**London** Imperial College of Science and Technology		Visit to the Mathematical Machines Laboratory of Imperial College including an introductory talk by Dr. J. R. Barker, A.Inst.P.	5.00 p.m.	Education
Mar. 3	**Aberdeen** The University	Professor J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.45 p.m.	Scottish
Mar. 4	**Edinburgh** The University	Professor J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.15 p.m.	Scottish
Mar. 7	**Glasgow** The University	Professor J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.15 p.m.	Scottish
Mar. 10	**Liverpool** The University	Prof. G. D. Rochester, F.Inst.P., F.R.S. (*University of Durham*)	**Cosmic rays in outer space**	7.00 p.m.	Liverpool and North Wales

Reviews of Books

THE CORRESPONDENCE OF ISAAC NEWTON —VOLUME I

Edited by H. W. Turnbull

London: Cambridge University Press. Pp. xxxvii + 467. Price 147s.

This princely volume is the first of a series designed to do something (and in fact a very substantial "something") to remedy the extraordinary lack of published material by or directly relating to Sir Isaac Newton.* Considering the unique place which he occupies in the whole learned world, it is surprising indeed that there is no such thing as "The Complete Collected Works of Isaac Newton," or some similar corpus. One feels this yet more strongly when, as the introduction to the present book so aptly points out, there are available in appropriate form the labours of such giants as Descartes, Galileo, Huygens and Euler. How came it then that our own Newton seems to have suffered neglect? The causes are complex, and well explained: his genius spread over so wide a field (mathematics, physics, theology, chemistry, alchemy, coinage and the Mint) that only a sizeable team of experts could possibly have coped with the (approximately) three and a half million words involved. Again Newton was in the habit of copying out lengthy passages from various sources which happened to interest him, and to pass the time—when not heavily pressed—with interminable arithmetical calculations, such as his evaluation of the area of the hyperbola to a great number of figures. Clearly, these would in no event qualify for inclusion in a collection of papers. In the end, for this and a variety of reasons, it was agreed to bring out Newton's *Correspondence*, a decision which should go a long way to help scholars concerned both bibliographically and historically with the natural philosophy of the period. Such a project needs a worthy setting, which has indeed been achieved. Nothing could be a more fitting tribute than the meticulous care bestowed upon these letters by Professor H. W. Turnbull. His notes make the originals come alive again, and stand as an object lesson in the minutiae of scrupulous editing.

The documents before us show Newton the scientist, though with the exercise of some reading between the lines it is possible to discern Newton the man. The whole assemblage is of unique value in demonstrating the pattern of thought two-thirds of the way through the seventeenth century. Time and again these pages reveal Newton's reluctance to publish, due largely to his desire to avoid becoming embroilled in contemporary controversies. So much so that he was accustomed to use intermediaries to conduct some of his correspondence for him. One can imagine him engrossed in his mechanical and optical constructions (he had the flair and hands of a born experimentalist), not seldom exasperated by the objections and criticisms of lesser minds. But when approached courteously and with understanding, he would take infinite pains to satisfy the curiosity of the genuine enquirer.

In front of us are 156 items, 137 of which have been published before. (Horsley's five volumes 1779-85 cannot be taken very seriously; the exclusion of *De Moto* from them was a major omission). The general plan has been to include all letters written by and addressed to Newton *in extenso*. Besides these, come

* A warm welcome is naturally extended to the book *Isaac Newton's Papers and Letters on Natural Philosophy and Related Documents*. (C.U.P. 1958.)

extracts from contemporary letters which make reference to him, and then some shorter memoranda illustrative of Newton's life. When it is recollected that the whole enterprise started in earnest at such an inauspicious moment as July, 1939, it is a nine-day's wonder that it has reached so far towards fulfilment.

The earliest letter—to a sick friend—is *circa* 1661, the year Newton went up to Trinity, and then there is a gap until May 6, 1665, when he received a few lines from his mother at Woolsthorpe. Thereafter, we go to February 23, 1668/9. But in between much, of course, had happened. Driven from Cambridge by the plague (1665-7), he returned with his three momentous discoveries well on the way to fruition. These were, the nature of white light, the theory of universal gravitation, and the calculus, or in his terminology, the method of fluxions. In fact, Newton did not let the world know of his *Opticks* until 1704, the year after Robert Hooke's death, with whom unluckily he was so often to cross swords. In this distressing conflict, Oldenburg, the Secretary of the Royal Society from 1663 to 1677 seems to have acted tactlessly; he disliked Hooke, and apparently "baited" him excessively on Newton's behalf, whom he sincerely admired.

The year 1668 was an important one for Newton, for it was then that he was elected a major fellow of his college, and towards the end of it came the reflecting telescope made by himself.

In this context, letter No. 51 contains what is probably the earliest mention of the use of a right-angled prism in place of a plane metallic mirror, for the reflection of light into the eyepiece. But more intriguing still is the suggestion that if the two faces opposite the hypotenuse be made convex the effect will be to give an erect image, "by performing the office of a double convex lens." Newton also proposed a reflecting microscope in letter No. 40, to Oldenburg. Curiously enough, this ingenious proposition has only of recent years come to the fore, as the result of the need for long working distances in various industrial applications.

Much of this invaluable corrspondence should be a stimulus to research of every kind, both "pure" and "applied." Newton indeed is the classic instance of a master to whom those two adjectives must have been a distinction without a difference. His penetrating genius always urged him to ask how nature worked, and his mathematical skill went far to supply the answer. Newton's intellectual development was by no means precocious, however; he seems (as many lesser lights have done) to have undervalued Euclid in his early days, and to have been a somewhat poor geometer when he sat for, and obtained, a scholarship in 1664. (These well-known details do not occur in the text before us; they are mentioned to provide a background for the phenomenal insight which unfolded itself year after year as Newton's life progressed and his labours multiplied). He is the perfect example of the maturity which is reached when nature is not unduly hurried.

Some mention should be made of his relations with The Royal Society. He was elected a Fellow on January 11, 1671/2. This seems to have pleased him, but on March 8, 1672/3, we find him desirous to resign. His was a character easily "hurt," and he endured none too readily the "rudeness" of some of his contemporaries. Such, however, was the lot of one so high above all the heads of his time. With some financial and other adjustments these clouds seem to have dispersed, for (to anticipate) we know that he was elected President on St. Andrew's Day, 1703, and so remained for some five and twenty years.

In addition to the letters, the reader obtains an adequate reproduction—as frontispiece—of the Kneller portrait, and six plates of Newton's drawings, a letter and an early manuscript—altogether a good choice.

The production and format of this monumental book have a dignity and "feel" wholly commensurate with its great theme. As ill-luck would have it, however, there occurs on page xxxv (Acknowledgments), line 6, the almost incredible phrase "the Dean and *Fellows* (*sic*) of Christ Church, Oxford." How exactly this came about is anybody's guess, but it is "just a wee pity." Such a trifle apart, we have here, as only scholars can provide, the annotated correspondence of a supreme genius. Whom having set out to honour, they have done it well.

F. I. G. RAWLINS.

SCIENCE IN INDUSTRY

By C. F. Carter and B. R. Williams

London: Oxford University Press. Pp. ix + 186. Price 21s.

This book is the third of a series dealing with the utilization of science in industry written on behalf of the Science and Industry Committee. This Committee was set up six years ago jointly by The British Association and The Royal Society of Arts and its work has been supported by grants from the Nuffield Foundation, the Board of Trade and D.S.I.R. The Committee includes men of very varied experience whose views have been closely considered by the authors, who themselves are economists.

The book is in two parts. The first part deals with action required by industry in research, development and management techniques to promote technical innovation and the second is concerned with action by the Government, both in direct impact on scientific research and education and in the indirect field of taxation, credit policy, foreign competition and restrictive practices. Chapter sixteen gives a useful summary of the proposals.

The book presents a well-balanced picture which should be most valuable to people in industrial firms or concerned with the well-being of modern industry. It deals with most of the points which scientists with long experience of industry would consider important and is well illustrated with examples from industry and research.

Personally, I find the definitions of research and development which are accepted, rather confusing and out of line with those to which I have been accustomed, and the reiterated use of the term "parasitic" in circumstances where it could be construed as derogatory is, I think, unfortunate.

The recognition that an increased scientific content in general education at all levels is necessary, is timely. So is the consideration given to the effect of restrictive practices, including those of labour, on technical

innovation. In this connection I would have liked to have seen some discussion of the equally restrictive (though different) practices of "staff" and the part which modern scientific techniques of management can play in controlling the proliferation of specialist departments and overheads. Parkinson's Law might even have been mentioned.

Summarizing, the book is a well-balanced and valuable contribution to the study of the application of science and scientific techniques to utilitarian ends in industry and to the educational needs of a population living in a civilization based on science and technology.

JAMES TAYLOR.

SEMI-CONDUCTORS

By R. A. Smith

London : Cambridge University Press. Pp. xvii + 494. Price 65s.

The study of electronic semiconductors has increased at an astounding rate since 1945. Various specialist monographs are now becoming available but the number of texts attempting to cover the whole subject at what is generally called "Honours" level is small. Of these Dunlap's *Introduction to Semiconductors* was probably the best available until the appearance of Dr. Smith's new book. As Head of the Physics Department of the Royal Radar Establishment the author has been responsible for some of the major research effort on semiconductors in the U.K. This has given him a general grasp of the whole subject in a way which would prove well-nigh impossible for a more specialist worker. The author already has a reputation for excellence in his verbal expositions and his clarity of exposition has been carried over into the written work. The book may safely be allowed into the hands of students since the introductory nature of the exposition is not acquired at the cost of the errors of statement due to over-simplification which characterize certain other introductory works on the subject.

The treatment of the whole subject is covered in an even manner and the copious references give credit to the contributions of British workers in the field.

Apart from the more usual material the following topical subjects are treated ; carrier scattering mechanisms, effects of strong magnetic fields, exciton absorption, direct and indirect transitions, resonance phenomena, diffusion and recombination mechanisms, effects of crystal defects including dislocations on the semiconducting properties of crystals. About a quarter of the book is devoted to a description of the characteristic properties of a wide range of semiconductors and of their technical applications.

In short, the book is an excellent introductory text, well signposted with references and from which the specialist in one part of the subject may learn something useful from the even consideration of the subject of "Semiconductors" treated as a whole.

C. A. HOGARTH.

LECTURES IN THEORETICAL PHYSICS

Edited by Wesley E. Brittin and Lita G. Dunham

London : Interscience Publishers Ltd. Pp. vii + 414. Price 45s.

Now that publishers have tumbled to the idea that a steady and very safe profit can be made out of advanced books on physics, a minor avalanche has begun to descend upon the conscientious reader. In fact, the only limitation until recently has been the reluctance of physicists to put pen to paper and the time and expense involved in mathematical typesetting. These difficulties have now been overcome and soon even the most conscientious reader will have to give up. The method by which this has been done deserves a detailed description.

The first step is to get an important person, or preferably several such, to deliver a set of lectures. This can generally be arranged by organizing a postgraduate summer course in some pleasant holiday resort. The lectures are listened to attentively by several students and —most importantly—a tape recorder, while a 35mm camera takes frequent snaps of the blackboard. The resulting lecture notes are sometimes seen by the lecturers (in this case they were) before they are passed on to the Vari-typist and the person who writes in the equations. These for their arduous labours are generally immortalized in the preface. And so to photo-offset, between stiff boards—to make it look like a book—and into the shops.

I must admit that this process has produced very much worse books than the present one. The lectures are, with one exception, in theoretical high energy physics and deal with pair production, particles with zero rest-mass, strange particles, irreversible processes, meson production, nuclear structure and high energy collisions. They must have been a joy to listen to and in two cases, where the present reviewer has personal experience, he can vouch for it that the highly individual style of the lecturers has come through. But, as was right and proper for a summer school, the lectures are in many cases up to the minute without being complete in depth and background and thus they will tend to date quickly. It is possible that but for the process outlined above we might never have had anything at all by at least some of the authors and that would have been a great pity. It is virtually certain however that the publication of this book will effectively prevent them and others from treating the subjects presented here more fully and in greater depth for some time to come. And that is the greater pity.

L. R. B. ELTON.

CONTROL ENGINEERING

By Gordon J. Murphy

London : D. van Nostrand Co. Ltd. Pp. xii + 385. Price 56s.

As shown by his *Basic Automatic Control Theory*, Professor Murphy has a clear and logical mind and, as a result, writes in a leisurely manner, particularly suited to those unfamiliar with his subject. This results in rather greater length of text than is necessary for those well versed in the art but his books are intended for the student and for this purpose clarity of expression combined with accuracy are by far the most important requirements and these are well satisfied in this volume.

The introduction puts the simple methods of analysis of linear systems, which are discussed later in the book, in perspective and the first chapter is an extremely good exposition of the Laplace transform method of determining time response, which can be easily followed and leads on to the use of the method for design of a simple system. Interposed between these two chapters is one on components, in which the problem of determining the transfer function of given components is discussed and a most useful set of schematic diagrams of different types of component, illustrating electronic, electro-magnetic, mechanical, hydraulic and pneumatic types are given, together with their transfer functions. Following methods of design using Laplace transforms, frequency response methods are dealt with. This leads on to the analysis of carrier systems and, in a later chapter, to problems of noise and the concept of spectral densities of random functions. These chapters are easy to follow and give a nice introduction to the problems but it is a pity that having got so far, Professor Murphy has done no more than mention the statistical design of systems with random inputs. Although the method of optimization developed by Wiener and Newton is still difficult in application, it is the only certain method of obtaining the best system when high performance is required and we now know enough about the method for it to have been satisfactorily dealt with in one additional chapter. This would have been very much more worthwhile than the very brief introduction to non-linear systems given in the last two chapters, which give an introduction to the use of describing functions and the phase-plane. Besides the chapters already mentioned, there is a useful little chapter on systems with dead-time and a very good introduction to sampled data systems and the use of the " z " transform.

One of the greatest virtues of the book is the emphasis on the use of pole and zero configuration for approximate design and in Table 4.1 he gives the step response for eleven different configurations, which are most instructive. There is no doubt that if the control engineer has a clear understanding of the relationship between pole and zero configurations and frequency and time response, he will have little difficulty in designing a reasonably suitable system to meet a given specification. Neither the Root-Locus nor any other of the frequency response methods normally used can do more than this and in order to be sure of meeting a specification, statistical design methods must be used.

A wide range of examples are worked out in the text, which should greatly assist the student in understanding the methods described and there are useful problems to be worked out given at the end of each chapter. In his equations, Professor Murphy is meticulous that the terms are consistent, i.e. that they are all either time functions or transforms of one type or another but are not mixed. In his diagrams, however, he follows the common practice of mixing time functions with transfer functions, a habit which is to be deprecated. It is time that engineers, when they draw block diagrams in which transfer functions are indicated as transforms of one sort or another, show the input and output quantities in terms of the same transforms and if desired, show the time functions as well.

On page 156 there is some confusion owing to the numbering of figure references being incorrect and in the table of modulators on page 78, it would be better to show the transfer functions as approximately equal to K.

J. F. COALES.

FIFTH NATIONAL SYMPOSIUM ON VACUUM TECHNOLOGY TRANSACTIONS

Edited by Wilfrid G. Matheson

London and New York : Pergamon Press Ltd. Pp. 282. Price 100s.

Since 1954 the American Vacuum Society have held annually in the autumn a symposium on vacuum technology and the papers read have been published in book form. This volume, the fifth in the series, is the largest so far and contains 54 papers classified into the following sections : fundamental basis of vacuum techniques ; applied science and research ; vacuum instrumentation and controls ; education in vacuum technology ; ultra-high vacuum ; industrial applications and processes ; vacuum deposited magnetic and thin films.

The papers vary in quality and a few have undoubtedly been presented for prestige reasons rather than because they record new work. However, these proceedings are of great value because they make available the only annual account in book form of current research and development written by acknowledged authorities. Though the majority of the papers are concerned with work done in America, it is noteworthy that, each year, an increasing number are contributed by delegates from Europe. It is a tribute to American energy and enterprise that an organization little more than five years old is regarded as of such importance that attendance at its symposium, or the reading of its proceedings, is now regarded as essential by those who desire to keep up-to-date in this rapidly developing and exciting field.

Though comments on papers by the members of the audience are not usually worth recording in full, a summary at the end of each paper of any important issues raised would help the reader to judge the value of new processes, techniques and research described. A subject index at the end of the book would also be an advantage, even if it dealt only with major items.

The editing has been done well except that it is confusing to find two separate sections with the same heading " Industrial applications and processes," the first occupying pages 164 to 203 and the second pages 247 to 282.

The printing and publication are excellent. The high standard of the diagrams is especially attractive and important in a text devoted primarily to technology ; the large page size has helped greatly in this connection.

J. YARWOOD.

INFORMATION TRANSMISSION, MODULATION, AND NOISE

By Mischa Schwartz

London: McGraw-Hill Publishing Co. Ltd. Pp. xv + 461. Price 85s. 6d.

The excitement aroused by the publication of Shannon's statistical theory of communication has had

some ten years in which to die down whereas the discrepancy between the amount of information which can be transmitted over a practical channel and the upper theoretical limit seems still to be as great as ever. It is to be hoped, therefore, that by familiarizing the present generation of students with the concepts of information theory, we shall see more rapid progress in the future. This book is certainly a step in the right direction. That finite bandwidth and noise impose fundamental limitations upon the rate of transmission, is used by the author as the basis of what he calls a unified approach to the study of communication systems. One is left with the impression that he has only partly succeeded in his purpose. Information is, in fact, only mentioned in the introduction and near the end, where the capacity of a pulse code modulated channel is evaluated.

The first chapter provides an excellent introduction to the precise meaning of information, appealing to intuitive concepts to show the way in which it depends upon uncertainty and probability. In the remainder of the book the author adopts the well proven technique of enunciating physical principles and supporting them with mathematical analysis. He explains his methods and conclusions with painstaking clarity, and the senior student with but a moderate knowledge of algebra and calculus should have no difficulty in following the reasoning. The mathematical approach is, however, permitted an undue dominance, and aspects which do not fall into this pattern tend to be overlooked. In the section on single side band systems, for example, the student is encouraged to calculate the waveform received when the local carrier drifts but is given no guidance as to what order of drift can be tolerated before speech becomes unintelligible, or how to counteract the effect of the drift if digital data are to be transmitted.

Chapters 2 to 5 deal with transform methods, systems of modulation, sampling and noise as more or less separate topics. The unified approach commences with Chapter 6, entitled " Comparative Analysis of Information Transmission Systems." This Chapter could well have been expanded at the expense of some of the more elementary material readily available elsewhere. The considerations used in drawing the comparison are rather restricted and take no account of such effects as interference, phase distortion, fading and multipath propagation. It would also have been appropriate to discuss frequency versus time multiplexing, whereas only the latter is dealt with. Furthermore, the section on the exchange of bandwidth for signal-to-noise ratio does not indicate the way in which the threshold signal level—an important parameter in system design—also alters. The final chapter, on statistical methods and applications of the Wiener-Khintchine theorem, is good and the author is to be congratulated on his handling of this difficult topic.

Two weaknesses which should be pointed out are the index, which is very scanty and fails to list such names as Johnson and Shannon, and the lack of answers to the numerous numerical problems. Nevertheless, the book can be warmly recommended to the student, and to the system designer who wishes to brush up his understanding of the fundamentals of the subject.

R. H. Barker.

MOLECULAR SCIENCE AND MOLECULAR ENGINEERING

By Arthur R. von Hippal

London: Chapman & Hall Ltd. Pp. xv + 446. Price 148s.

This is the third volume of a monumental trilogy on modern material research. The first two volumes were concerned with the theory of dielectrics and their practical application. In a way, these dealt with materials as they are. The present volume takes the process a step further—molecular engineering is concerned with the building of materials to order. The theoretical background of this is molecular science, the science of the forces that bind matter, in solids, liquids or gases. The editor writes that for twenty years physicists, chemists, electrical engineers and ceramists have worked together in the M.I.T. Laboratory for Insulation Research of which he is the director, and one outcome of this work is clearly the creation of this new specialist, the molecular engineer, a specialist moreover that would appear to have to be a Jack in all the trades of physical science.

Professor von Hippel himself has written over a third of this volume and the rest, written by his collaborators, bears the stamp of his authority and immense knowledge. As even von Hippel could not write the whole himself, the best the critic can do is to examine those parts of the book which concern his own speciality for completeness, for clarity of presentation and for lack of errors, and to examine the rest from the point of view of the outsider who wishes to broaden and deepen his knowledge. On all these counts the work passes with honours.

It is clear that the price will prevent the book from being bought by any considerable number of private persons and it is equally clear that its encyclopaedic content and splendid presentation makes its purchase compulsory for any library that has pretensions to keeping its readers in touch with the frontiers of science and technology. A detailed critical review of the contents is therefore unnecessary and would in any case be impertinent. There are, however, some more general thoughts provoked by the book that are worthy of further elaboration.

The first concerns this matter of presentation. There is the problem of treating difficult and highly specialized subjects in such a manner that the non-specialist not only obtains an understanding of the subject, but can actually make use of it, and there is the typographical rendering of it on the printed page. On both these matters we in this country can learn much from this book, as from many another, though by no means every American textbook. Let us take the smaller, second point first. There seems to be an opinion current here that such frivolities as book design are out of place in serious textbooks, except perhaps on the dust cover where in some cases the boys from the sales department have made their presence felt in their attempt to chromium plate the lily. But just as the lay-out of *The Times* of to-day makes it more readable than the *Daily Mail* of fifty years ago, so the intelligent use of headings and sub-headings, of graphs, tables and displayed equations to break up the page makes this book a pleasure

to read without in the least distracting from the weightiness of the subject matter.

But it is our lack of success with regard to the first point that must cause us serious concern. Textbook writing is a despised profession in this country, and the result is that books are generally written either by specialists for specialists, which is respectable but not profitable, or by popularizers for the mass market which tends to be the opposite. The great but very worthwhile effort demanded in trying to get our work understood by the man in the neighbouring department is seldom made. We withdraw into our little shell, as he does into his, and lament that the day of the polymath is past. In this way we stultify the progress of science and prevent the emergence of new industries.

The second thought that must occur to every reader of this book concerns the relationship of research in science and technology. We have recently designated some of our technical colleges as Colleges of Advanced Technology and the debate now rages as to what is their peculiar function and particularly in which way their research should differ from that of the universities. Dr. Venables in a recent book draws attention to an opinion that is apparently widely held that research in C.A.T.s should be largely utilitarian and that pure research should be the province of the universities. The truth of the matter is—and technological institutions as far apart as Cambridge, Mass. and Zürich recognized this decades ago—that while pure research can flourish by itself, applied research cannot. Universities are therefore at liberty to restrict themselves to the pure sector, but Colleges of Technology restrict themselves to the applied at the risk of death by slow starvation. This book shows how in one large field of research the pure and the applied have been combined and how, as a result, the whole is greater than the sum of its parts.

L. R. B. Elton.

SCIENTIFIC MANPOWER

By Joyce Alexander

London: Hilger & Watts Ltd. Pp. viii + 134. Price 15s.

This well-produced little book is based largely on information obtained while the author was on the staff of the Science and Industry Committee of the British Association. It is difficult to see who might need or profitably use it. Most of those sufficiently interested in the subject to read a book on it will already know the sources from which Mrs. Alexander quotes the inevitable—and now wearisome—statistics. Mrs. Alexander has obviously collected a great deal of information but she offers no really authoritative discussion of the data she has assembled. She writes well but her comment is, in my view, almost everywhere superficial or—as in part of the chapter on scientific womanpower—irrelevant. There is a twenty-two-page chapter on *technological* training in other countries and it is interesting to note the allocation of space: France—9 pages, Western Germany—4½ pages, Italy—2 pages, Switzerland—2 pages, Russia—2¼ pages, U.S.A.—1 page, Canada—1 page, Holland—no mention. The proof that this may be reduced to either rhyme or reason is—as the geometry textbooks say—left to the reader.

Norman Clarke.

STRANGE WORLD OF THE MOON

By V. A. Firsoff

London : Hutchinson & Co. (Publishers) Ltd. Pp. x + 226. Price 25s.

If it were not for the subtitle " an enquiry into lunar physics " we might well doubt whether the Moon concerns readers of the *Bulletin*, or whether it might not be left to the non-scientific romantic. But the book is not just the conventional list of surface features and their imaginative names. Genuine physical problems of the atmospheres possible to a satellite are discussed, and the situation arises that lunar occultation of radio sources can conceivably indicate electron densities not solely those of interplanetary space. Modern queries as to thermal properties of lunar material are shown to be as controversial as the famous ambiguity between volcanic and meteoric origin of the craters.

Martin Johnson.

MASERS

By Gordon Troup

London : Methuen & Co. Ltd. Pp. x + 168. Price 13s. 6d.

This is a well-written book on a relatively new topic of considerable interest and importance. Amplification with very low noise-level at microwave frequencies is an important subject at the present time, and the use of stimulated emission in gaseous and in solid-state devices has made a most valuable contribution to progress in dealing with this problem.

The book presents the theory of the process of stimulated emission as contrasted with spontaneous emission, and discusses the conditions which must be met in order to achieve amplification, with particular reference to the use of transitions between the different states of a paramagnetic molecule. The basic requirement is that there shall be a sufficient number of molecules in the upper of two states, and methods of excitation to achieve this are considered. This leads to a discussion of means of obtaining practical amplifier systems, firstly in a line amplifier and then in a resonant cavity. In both cases there is a detailed treatment of the gain and bandwidth, and particularly of the origin of the low noise factor. The oscillator is then considered, and the experimental work on gaseous and solid-state devices. Finally there are some comments about the possible developments in the future.

The subject of masers is probably considered widely at the present time as a " difficult " one. The mathematical arguments are clearly presented in this book, and it should prove successful in leading to a wide-spread understanding of the basic principles.

D. A. Wright.

INTRODUCTION TO THE MECHANICS OF THE SOLAR SYSTEM

By Rudolf Kurth

London : Pergamon Press Ltd. Pp. ix + 177. Price 42s.

This is an excellent introduction at research level to planetary dynamics. In spite of the author's disclaimer, the mathematical demands are fairly severe, but relieved by occasional brief and clear physical account. It seems a pity that the ratio of price to pages aims at setting a record unlikely to be beaten, extremely discouraging to any purchaser except subsidized libraries.

MARTIN JOHNSON.

AN INTRODUCTION TO CHEMICAL NOMENCLATURE

By R. S. Cahn

London : Butterworths Scientific Publications. Pp. viii + 96. Price 10s. 6d.

Your reviewer, trained as a chemist, long ago transferred his activities to physics. A short perusal of this book does not make him regret this change. Chemistry is not what it used to be ; and the nomenclature of chemistry (though the author restricts this remark to organic chemistry) is " an infuriating subject."

All nomenclatures, like the porpoise in *Alice in Wonderland*, are necessary evils : that of chemistry seems far worse than the nomenclature of physics, which is evidently a more equalitarian science. The order of precedence of groups of atoms (" radicals " would surely sound out of place in this connection) would delight the heart of a Lord Chamberlain. Only in one place does the physicist appear to be worse off than the chemist : he may require to label the symbol for an atom with more than the four attributes allowed to the chemist.

The author of this work tackles his infuriating subject with zest and courage and, in so small a volume, has produced, with a singular lack of misprints, a mine of boring yet essential information which should be very welcome to those physicists unfortunate enough to have to deal with such matters.

One of the best criteria for the value of such a book is the completeness of the index which, in this case, appears to be most adequate.

Shall we say that this is a book that many physicists should have on their shelves, piously hoping that it may stay there undisturbed ?

G. W. SCOTT BLAIR.

METHODS OF EXPERIMENTAL PHYSICS—VOLUME 6 SOLID STATE PHYSICS

Edited by K. Lark-Horovitz and Vivian E. Johnson

New York and London: Academic Press Inc. Pp. xiv + 416. Price 88s.

In its " Recent Advances " series the Academic Press has served a most useful purpose in publishing up-to-date reviews of various selected branches of pure and applied science, compiled by specialists. The series from which the book under review is taken still uses specialists, but it differs from the other series in that it attempts to cover a whole field—the methods of experimental physics. The present book is the second half of volume 6 on solid state physics, and it deals with electrical, magnetic and optical properties of solids. There are 26 different sections, all with different authors. A few selected headings are dielectric measurements, superconductivity, high frequency effects in semiconductors, surface states, Hall Effect, ferromagnetism and ferrimagnetism, optical measurements on thin films, electronic band structure by X-ray spectroscopy, luminescence, and photoelectricity. In most sections there is a brief summary of the basic principles which are the subject of the experimental methods. Although there is some detailed description of apparatus the book is much more than a catalogue of experiments.

Amongst the weaknesses of a many-author compilation are the variation of style, danger of repetition and lack of co-ordination. The present volume suffers to some extent in these ways. For example, certain aspects of photoelectricity are discussed in the section on thermionic emission as well as in the optical section. There is some repetition, with no cross references and with different symbolism. These faults are probably inevitable and are the price to be paid for an authoritative coverage of a very wide field. Although there is some deficiency in cross reference within the book, there are numerous references to original papers.

On the whole this volume appears to be remarkably successful. It will be welcomed not only as a reference source for research workers but also in teaching establishments dealing with advanced laboratory courses in physics.

M. R. GAVIN.

The Institute's Journals

PRINCIPAL CONTENTS OF THE FEBRUARY, 1960, ISSUES

Journal of Scientific Instruments : Volume 37, No. 2

X-ray diffraction by single crystals at low temperatures : a cryostat for use with liquid hydrogen. By J. H. Robertson.

Techniques for cooling a single crystal in X-ray work are discussed, and the merits of the continuous gas-stream method are noted. It is shown that hydrogen gas has properties which render it especially suitable for use in this way.

A simple modification of the usual method for generating

the cold gas stream is described. The apparatus is capable of maintaining a crystal at a temperature of about 23°K (using hydrogen) for periods up to 48 h, without interference with the operation of standard diffraction techniques.

Simple device for use with platform weighbridges in the accurate determination of burning rates. By J. E. Roughton, A.Inst.P.

The device comprises an automatically adjusted "chain rider" which permits measurement of small weight changes to better than $\pm\frac{1}{2}$ oz with a normal 5 cwt platform weighbridge.

An electroluminescent digital indicator with a silicon carbide coding matrix. By D. H. Mash.

A digital indicator is described using an electroluminescent panel having its back electrode shaped as an array of lines, from combinations of which the digits are formed. Also described is a coding matrix which greatly simplifies the electrical switching needed for the indicator. The coding matrix utilizes the non-linear electrical properties of silicon carbide powder to discriminate between the voltage applied to wanted elements and unwanted elements, and allows a single-pole ten-way switch to be used for selecting the required digit.

Some techniques for recording and measuring time-resolved spectra. By A. H. Gabriel, A.Inst.P.

Methods are considered of recording the time-variation of the spectra of microsecond phenomena. An apparatus is described employing a rotating mirror time-resolving device before the slit of a quartz photographic spectrograph. Writing speeds of up to 5·1 mm/μs are obtained. Consideration of possible calibration techniques involves some preliminary results on reciprocity law failure at very short exposure times. A pulsed calibration source is described in which a continuum at 26,000°K is maintained for 15μs, and this is used to provide an absolute calibration of the records.

An electromicrobalance for weighing fibres. By F. R. Morgan, A.Inst.P.

An electromicrobalance is described that has a capacity of about 1·5 mg and weighs to about 1 μg.

Portable airglow photometer. By B. J. O'Brien and G. De La Harpe.

A simple, direct-reading and sensitive photometer which is easily transported and is independent of external power supplies is described. Details of the optical system and the electronic circuitry are given, and the performance of the apparatus is discussed.

Direct method for determining the velocity of nuclear particles. By B. F. Hampton.

A new method of directly determining the velocity of nuclear particles in a cloud chamber is described. It is not necessary to know the mass or charge of the particle, and measurements of radius of curvature are not involved. The principle is to make the cloud chamber in the form of a resonant microwave cavity, the electric field in the cavity being very close to breakdown. Under these conditions additional ionization takes place when the electric field is a maximum, i.e. twice per cycle, resulting in a track that is modulated in intensity. With an applied field of 3000 Mc/s the time marks are spaced at intervals of 2·7 mm for an α-particle having an energy of $5{\cdot}6 \times 10^6$eV. The apparatus is described, and a method of feeding 85% of the output of a magnetron into a resonant cavity is given. A certain amount of success was obtained using hydrogen as the working gas. Limitations of the apparatus are discussed and further improvements suggested.

Recording calorimeter for the measurement of heats of wetting, mixing, or solution. By F. A. P. Maggs and P. H. Schwabe.

A calorimeter has been designed for the measurement of heat liberations of less than 50 cal. Automatic temperature recording with variable amplification has been linked to the measuring thermocouples to produce a permanent record of temperature changes in the calorimeter. Magnetically operated stirring and reaction initiation (by bursting an evacuated bulb containing adsorbent or reagent) are employed. Electrical calibration is made for each system before and after bursting the bulb. The use of the calorimeter in measuring the heat of wetting of charcoal and the heat of mixing of water and methanol is demonstrated. Application of the calorimeter to other thermometric procedures within the mechanical limitations of the instrument is discussed.

Twin-head goniometer for the study of diffusely reflected X-rays. By W. A. Wooster, F.Inst.P., and G. A. Wooster.

The apparatus described is a modified commercial single-crystal X-ray goniometer. Two goniometer heads are mounted on the vertical axis of the instrument so that two crystals may be placed alternately in the X-ray beam. The recording photographic film moves with the crystals and two records of diffuse reflexions, one a standard and the other the unknown, are obtained on the same film and with a known ratio of their exposure times. Thermal diffuse scattering from one (standard) crystal is used to determine the intensity of the incident X-ray beam. The thermal or structural X-ray reflexion from the second crystal may then be found in absolute measure.

British Journal of Applied Physics: Volume 11, No. 2

Recent studies of noise problems. By G. G. Parfitt.

Some fairly recent work on various aspects of acoustic noise was reviewed at a half-day symposium held in London in March, 1959, by the Acoustics Group of The Physical Society. One group of papers discussed studies of the parameters of noise which were important in determining the subjective loudness, the possible damaging effect on human hearing, the influence on working efficiency and the annoyance caused in residential and working communities. Of the more purely technical papers, one considered some of the difficulties in making measurements of noise from aircraft to the relatively high degree of accuracy often required, while the other described results of measurements and analysis of the noise from automative diesel engines.

High resistivity nickel-iron alloys with rectangular hysteresis loops. By A. Hart.

Because of its rectangular hysteresis loop, magnetically annealed 65/35 nickel-iron alloy is suitable for many applications. The alloy has a low resistivity, however, and eddy-current effects limit the performance of many devices made from the alloy. An alloy with similar magnetic characteristics and a higher resistivity is very desirable.

A method of magnetic annealing is described which allows magnetic properties, practically identical to those of 65/35 alloy, to be induced in alloys containing up to 3% molybdenum, and nickel and iron in the ratio 65/35. The resistivity of the 3% molybdenum alloy is 53 μΩ cm, compared with 19 μΩ cm, for the binary 65/35 alloy. The new annealing method takes rather longer than that previously used, but is no more difficult to carry out; it can be used on alloys which cannot be successfully treated by a "normal" magnetic anneal. Compared with available 50/50 grain-oriented alloy, the 3% molybdenum alloy has a lower coercivity and a higher resistivity, but its saturation flux density is some 20% less.

Viscosity and thermal conductivity of liquid boron trifluoride. By A. N. Spencer and M. C. J. Todd, A.Inst.P.

The normal liquid range of boron trifluoride is −100° to −127°C. Conventional methods have been adapted to measure viscosity and thermal conductivity throughout this range of temperature, and experimental results are presented.

Absolute intensity measurements of the carbon and aluminium X-ray K-lines with a proportional counter. By R. M. Dolby.

The efficiencies (quanta per electron per unit solid angle) of thick target carbon and aluminium X-ray K-line production, as a function of accelerating voltage, have been measured and plotted in the region below 10 kV. The construction and performance of the proportional counter, with which the measurements were made is also described.

Investigation into one of the assumptions of the Hertz theory of contact. By C. Storey.

One of the limitations of Hertz's solution of the contact problem is the assumption that, in the neighbourhood of contact, the surfaces of the bodies and, hence, the distance between their corresponding points can be represented by second degree equations. Subsequent theoretical work, mainly by I. Ya. Shtaerman, has provided a more general solution free from this limitation. It is the purpose of the present work to examine the effect of the inclusion of terms of higher degree than the second in the expression for the distance between the two bodies. Attention is confined to spheres and cylinders.

What is ferromagnetic resonance ? By R. A. Waldron, A.Inst.P.

It is pointed out that two distinct resonance effects take place in ferrite samples at microwave frequencies : ferromagnetic resonance and an effect due to the shape of the specimen. The latter effect is called Kittel resonance in this paper. It is commonly supposed that the two effects are the same, but it is shown that this is not the case. In ferromagnetic resonance, the diagonal and off-diagonal elements of the permeability tensor (μ and α respectively) exhibit anomalous dispersion, and microwave fields are excluded from the specimen. In Kittel resonance, nothing spectacular is happening to μ and α, but the fields in the specimen become very large, giving rise to a large loss ; it is this effect that is observed in resonant cavity experiments. The behaviour of cavities and waveguides containing ferrites is discussed in the light of these facts, and a new interpretation is arrived at of certain effects in waveguides when $|\mu| < |\alpha|$.

Evaporation and diffusion rate measurements on cathodes of sintered nickel containing alkaline-earth oxides. By J. F. Richardson, Grad.Inst.P., and Prof. F. A. Vick, F.Inst.P.

The evaporation rate of barium from a sintered nickel cathode and the diffusion rate of barium through it have been measured using ^{140}Ba and tracer techniques. Confirmation of the evaporation rates thus determined have been obtained by comparison with measurements made by a method due to Becker.

The activation energy of evaporation is 2·2 to 2·5 eV. Two diffusion processes operate, one predominant in the range 875 to 1020°C and one below 875°C. The activation energies are 2·5 and 0·5 eV respectively. The mechanism of diffusion at the higher temperatures appears to be Knudsen flow following evaporation from the inner surfaces, and that for the lower temperatures probably by surface diffusion.

Relaxation times in lead film, superconductive, storage elements. By R. F. Broom and O. Simpson.

An important factor in the performance of any thin film, superconductive, switching device is the speed with which superconductivity is restored after the film is driven into the normal conducting state. An experiment is described which measures the critical current of a lead film Crowe cell during the first microsecond after switching. The minimum writing time of such storage cells should be equal to the time required for the critical current to recover to one half of its initial value. Good correlation is found between the recovery times and the writing times for Crowe cells deposited on various substrates. Cells deposited on mica or sapphire recovered in 50 mμs, while those on glass required approximately three times as long. Measurements were also made of the critical current as a function of temperature, and these are used to derive cooling curves during the recovery phase. The cooling curves are not related to the thermal conductivities of the substrates in any simple way, probably because the rate of cooling is determined primarily by the thermal resistance between film and substrate.

Microcracks, and the static and dynamic elastic constants of annealed and heavily cold-worked metals. By J. R. Bristow, F.Inst.P.

The existence of sub-microscopic cracks in heavily cold-worked metals has been suggested in explanation of the very large discrepancies in dislocation densities estimated from changes in density and electrical resistivity, and release of stored energy on annealing such materials.

It is shown that microcracks will produce changes in the elastic constants of a material comparable with—but somewhat larger than—the change in electrical resistivity, rather than with change in density.

Measurements have been made, both statically and dynamically, of Young's modulus, the shear modulus and Poisson's ratio for annealed and heavily cold-worked aluminium, copper and nickel. No changes in moduli were found that could be ascribed to the presence of microcracks.

An unexpected result is a very large and consistent difference between the bulk moduli, and Poisson's ratio, determined statically and dynamically—a difference very much greater than can be accounted for by the usual thermodynamic relationship between isothermal and adiabatic moduli.

Theory of the parallel plate viscometer. By A. N. Gent, A.Inst.P.

The theoretical treatment for the rate of approach of two parallel circular plates separated by a viscous liquid is subject to the limiting condition that the separation of the plates must be small compared to the test-piece radius. The theory is extended to apply to test-pieces of any thickness and the modified treatment is shown to be in accord with experimental measurements on a sample of coal-tar pitch.

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